STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GYPSUM IN CALIFORNIA

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DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

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GYPSUM IN CALIFORNIA

By WILLIAM E. VER PLANCK

LETTER OF TRANSMITTAL

To His Excellency, The Honorable Earl Warren
Governor of the State of California

Dear Sir: I have the honor to transmit herewith Bulletin 163, *Gypsum in California*, prepared under the direction of Olaf P. Jenkins, Chief of the Division of Mines. Gypsum represents one of the important non-metallic mineral commodities of California. It serves particularly two of California's most important industries, agriculture and construction.

In Bulletin 163 the author, W. E. Ver Planck, a member of the staff of the Division of Mines, has prepared a comprehensive treatise covering all phases of the subject: history of the industry, geologic occurrence and origin of the mineral, mining, processing and marketing of the commodity. Specific gypsum properties were examined and mapped. The report is profusely illustrated by maps, charts and photographs. In the preparation of the report it was necessary for the author to make field investigations, laboratory and library studies, and to determine how the mineral is used in industry as well as how it occurs in nature and how it is mined.

This bulletin represents one of the results of the program of mineral commodity studies in which the Division of Mines is engaged.

Respectfully submitted,

Warren T. Hannum, Director
Department of Natural Resources

June 20, 1952

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GYPSUM IN CALIFORNIA

By William E. Ver Planck *

ABSTRACT

The known gypsum resources of California are restricted to the southern and southeastern parts of the state. Gypsum ($CaSO_4 \cdot 2H_2O$) most commonly occurs as rock gypsum of high purity interbedded with saline deposits or clastic sediments or as the efflorescent, earthy variety gypsite with a gypsum content ranging up to 80 per cent. Gypsum of pre-Tertiary, possibly Paleozoic, age is represented by deposits near Midland, Riverside County, where steeply dipping lenses and beds of coarsely crystalline rock gypsum are associated with mildly metamorphosed marble and clastic sediments. Tertiary gypsum deposits in California, associated with late Miocene or early Pliocene non-marine sediments, are represented by the Fish Creek Mountains deposit, Imperial and San Diego Counties, the Quatal Canyon deposit, Ventura County, and by a number of small deposits in the Death Valley area and other parts of the state. Certain playas contain abundant coarse selenite crystals that have been mined. Gypsite deposits, formed by the evaporation of gypsum-bearing ground water, occur in regions of little rain and high evaporation. Gypsite is mined in the southwestern part of the San Joaquin Valley, at Koehn Lake, Kern County, Carrizo Plain, San Luis Obispo County, and has been mined elsewhere in the past. Rock gypsum is quarried by methods and equipment commonly used for obtaining broken stone. Underground mining has been practiced. Gypsite is mined with carryall scrapers and other earth-moving equipment. Agricultural uses account for about half of the gypsum used in California, most of which is used in the San Joaquin Valley. An estimated 90 per cent of the agricultural gypsum is gypsite mined within 200 miles of the farms, and the remainder is ground rock gypsum. The portland cement industry uses uncalcined rock gypsum as a retarder. Most of the rock gypsum produced in California, supplemented by gypsum brought from Gerlach and Las Vegas, Nevada and from San Marcos Island in the Gulf of California, is calcined by the plaster industry and made into plasters, wallboard, and lath. The plaster industry is characterized by large integrated companies that own their own gypsum deposits. California has five calcining plants, one in the San Francisco Bay area, two near Los Angeles, and two in the southeastern desert close to gypsum deposits. The metropolitan plants obtain gypsum from out-of-state sources.

INTRODUCTION

No complete study of the gypsum resources of California has previously been published. There are, however, two geologic studies; both were made when the California gypsum industry was in its infancy. The work of Fairbanks [1] comprises a few remarks about the location and general character of the California deposits and brief descriptions of 15 localities. In the winter of 1906 and 1907, F. L. Hess studied most of the then important deposits and prepared the most complete published description.[2] Hess was among the first to realize the superficial character of the gypsite deposits. In 1920 Hess' work was republished substantially in its original form, together with some additional data contributed by other authors.[3]

The mining and processing of gypsum in California has not been summarized although individual operations have been described in reports of the California Division of Mines.

In the present report, the geologic occurrence, mining, preparation, and utilization of gypsum are described. Except where noted, only those deposits and operations actually visited are described in the text; they,

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* Assistant Mining Geologist, California Division of Mines. Manuscript submitted for publication February, 1952.

[1] Fairbanks, H. W., Gypsum deposits in California, *in* Adams, G. I., and others, Gypsum deposits in the United States: U. S. Geol. Survey Bull. 223, pp. 119-123, 1904.

[2] Hess, F. L., A reconnaissance of the gypsum deposits of California: U. S. Geol. Survey Bull. 413, 37 pp. 1910.

[3] Hess, F. L., California, in Stone, R. W., and others, Gypsum deposits of the United States: U. S. Geol. Survey Bull. 697, pp. 58-86, 1920.

together with all others mentioned in the literature, are included in the tabulated lists. The numbers following deposit, mine, or plant names refer to the numbered localities on the index map (plate 1).

Time permitted the detailed geologic study of only three gypsum deposits, which are representative of the types found in California. They are the Little Maria Mountains deposit, studied in February and March 1949, the Fish Creek Mountains deposit, studied in March and April 1950, and the Quatal Canyon deposit, studied in May 1950. The Little Maria Mountains study was undertaken as a thesis submitted to the School of Mineral Science and the Committee on Graduate Study of Stanford University in partial fulfillment for the degree of Master of Science. This material has been modified for inclusion here. Thirty-seven other deposits were visited and are described briefly, some with the aid of large-scale geologic cross sections. The location and accessibility of the deposits was emphasized.

The descriptions of the processing plants are based on plant visits, supplemented by recently published descriptions. Unfortunately, it was not possible to visit plants of the United States Gypsum Company.

The Gypsum Industry

During 1949 the gypsum industry of the United States produced gypsum and gypsum products valued at $158,746,367. California was exceeded only by Michigan and New York in the tonnage of gypsum mined in 1948 but slipped into fourth place in 1949.

The uses of gypsum are many. It is used uncalcined as an agricultural mineral. In California as much as half the total production has been used for agricultural purposes, although for the United States as a whole gypsum plays a minor role in agriculture. In 1949 nearly 80 percent of the agricultural gypsum consumed in the United States was sold in California. The portland cement industry is another large consumer of uncalcined gypsum. Added in the amount of 2 to 3 percent to the clinker before the final grinding, gypsum retards the setting of the cement. Other minor uses for uncalcined gypsum include fillers, brewer's fixe, blackboard chalk, and many others. Alabaster of good color and high quality is suitable for carving.

Gypsum that has been partly dehydrated by calcining at low heat is known as plaster of Paris, a material that possesses the useful property of setting when mixed with water. Much of the country's output of calcined gypsum is consumed by the building industry. Hardwall plaster is calcined gypsum to which has been added fiber and a retarder. Smaller quantities of sanded plaster, gaging plaster, and many special types of plaster are used in building. A large proportion of the gypsum supply is made into prefabricated articles. Of very great importance is gypsum wall board, lath, and sheathing board. Gypsum tiles of many sizes and shapes are consumed in smaller quantities. In addition there are a great many industrial processes that require special plasters of high quality. There are plasters for the plate glass and terra-cotta industries, for pottery, for orthopedic and dental use, for statuary, for industrial casting and molding, for polishing, and for many other purposes.

Gypsum is a low-priced commodity. The average value of crude gypsum at the mine reported by United States producers in 1949 was $2.75 per short ton, while the average value of gypsum mined in California was about $2.45 a ton. The price of finished products ranges from about $10

to over \$70 a ton, averaging perhaps \$15.00. It is apparent that the gypsum industry is essentially a manufacturing industry.

Gypsum is a broadly distributed commodity. The utilization of a gypsum deposit depends usually on economic rather than technical factors. Factors of importance include cost of mining, cost of transportation, and the cost of manufacture which in turn is influenced by the size of the market available to the plant.

In California gypsum deposits exist in 14 of the 58 counties. The largest reserves lie in the southeastern deserts; deposits of possible commercial interest are not known north of Merced County. Rock gypsum of 90 percent or better gypsum content is mined in the Fish Creek Mountains, Imperial County; the Little Maria Mountains, Riverside County; and Quatal Canyon, Ventura County. Large but undeveloped reserves are to be found in the Palen Mountains and Riverside Mountains of Riverside County and in the Avawatz Mountains of San Bernardino County. Much of the gypsum used for agricultural purposes is gypsite that contains from 70 percent to less than 50 percent gypsum. Gypsite mining is centered in the west side of the San Joaquin Valley from McKittrick in Kern County to Ortigalita Creek in Merced County.

California is supplied with crude gypsum from two other sources. Synthetic gypsum is a byproduct of several chemical processes. At present it is produced by the Westvaco Chemical Division, Food Machinery and Chemical Corporation at Newark, Alameda County, in connection with the manufacture of sea water magnesia. Much gypsum comes from out-of-state sources. Since the earliest days of the California gypsum industry, gypsum has been shipped from San Marcos Island near Santa Rosalia in the Gulf of California. The amount of gypsum imported from San Marcos Island in 1949 amounted to a fifth of that produced by California mines. In addition both crude gypsum and gypsum products come from Gerlach and Arden, Nevada.

The California gypsum industry is centered in southern California, and four of the five calcining plants are located there. These plants consume gypsum mined in California supplemented by supplies from out-of-state sources. Northern California is largely dependent on out-of-state sources for both crude gypsum and manufactured gypsum products.

Geologic Occurrence

Gypsum ($CaSO_4 \cdot 2H_2O$) and anhydrite ($CaSO_4$) are the two naturally occurring solid phases of the system $CaSO_4$—H_2O. Several additional members can be prepared in the laboratory under controlled conditions. These include two forms of the hemihydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$) and two forms of soluble anhydrite which may contain as much as 1 percent H_2O. All four of these unstable members may form in the commercial calcining kettle and are therefore of more than theoretical interest.

Pure gypsum is composed of 32.5 percent CaO, 46.6 percent SO_3, and 20.9 percent H_2O. It crystallizes in the monoclinic system. Perfect cleavage in one direction and hardness of 2 are diagnostic properties. Gypsum may be transparent to opaque, and white, gray, yellowish, or brownish in color. It is slightly soluble in water but dissolves readily in hot hydrochloric acid without effervescence.

Most commercial gypsum is a massive fine- to medium-grained material known as rock gypsum. Often it contains as much as 10 percent of silica

and calcium carbonate, and it may be dark-colored. Some fine-grained impure gypsum cannot be readily scratched with the fingernail. Gypsite, an earthy mixture of very small gypsum crystals and clay or sand, is also important commercially. Alabaster is fine-grained, white, often translucent, rock gypsum suitable for carving. Crystalline gypsum, known as selenite, occurs in transparent, cleavable masses or crystals. Satin spar is fine, fibrous, silky lustered gypsum that is found in veins of ground water origin. Ordinarily selenite and satin spar are not commercial sources of gypsum.

Anhydrite is composed of 41.2 percent CaO and 58.8 percent SO_3. It occurs in crystalline masses, usually granular but sometimes fibrous, that are white to pale shades of gray, blue, or red. Having a hardness of 3 to 3.5 and specific gravity of 2.89 to 2.98 it may be confused with limestone or dolomite in the field. Under the petrographic microscope anhydrite may be distinguished from both calcite and gypsum by its rectangular cleavage, moderate relief, and second to third order birefringence.

Gypsum is nearly always associated with anhydrite. Much evidence indicates that gypsum is the stable phase of calcium sulfate at the surface and that at depths of two to three hundred feet calcium sulfate is likely to occur as anhydrite.

The largest and commercially most important deposits are rock gypsum interbedded with sedimentary rocks. In California rock gypsum occurs in Tertiary non-marine clay and arkosic sand and in pre-Tertiary limestone that has been subjected to mild regional metamorphism. The earthy variety gypsite that forms on the outcrops of gypsiferous formations in arid regions contributes a substantial proportion of the California production. The crystal bodies of certain playa lakes are rich enough in gypsum to be possible commercial sources. Gypsum and anhydrite are also known to occur as part of the gangue in hydrothermal veins and as replacements of limestone. Near-surface veins formed by deposition from ground water are frequently found but are rarely a commercial source of gypsum.

PART 1

GEOLOGY OF CALIFORNIA GYPSUM DEPOSITS

PART 1

CONTENTS

PRE-TERTIARY DEPOSITS

Gypsum deposits of pre-Tertiary age occur in eastern Riverside County and are best known in the United States Gypsum Company and Garbutt and Orcutt properties in the Little Maria Mountains near Midland. The gypsum, a coarse-grained material of high purity, occurs interbedded with steeply dipping limestone, quartzite, and green schistose rocks. The Little Maria Mountains deposit extends eastward into the Maria Mountains; Miller[4] has proposed the name Maria formation for the gypsum-bearing rocks. From crinoid remains found in limestone associated with the gypsum the age was determined to be Paleozoic, possibly Silurian,[5] but the Maria formation might be the metamorphosed equivalent of the gypsum-bearing Moenkopi or Kaibab formations of Clark County, Nevada.

Deposits similar to those of the Maria and Little Maria Mountains occur in the Palen Mountains and Riverside Mountains, but only development work has been done.

Little Maria Mountains Deposits, Riverside County

The gypsum deposits of the Little Maria Mountains were for a 15-year period prior to 1940 the largest single source of gypsum in California. Since that time production has remained about the same, but as a gypsum-producing district the region has been overshadowed by other areas. The gypsum deposits occur in a belt of pre-Cretaceous rocks that crosses the Little Maria Range at a point about 25 miles northwest of Blythe. The same rocks extend eastward into the Maria Mountains where gypsum deposits also exist. The town of Midland lies on this belt in the pass between the Little Maria and Maria Mountains. The Blythe-Rice road, which passes through Midland, is paved between Blythe and Midland; and Midland lies on the Ripley branch of the Santa Fe railroad.

Two gypsum producers have been active in the area. First and foremost is the United States Gypsum Company, primarily a producer of calcined gypsum products, whose plant is at Midland. Raw gypsum is obtained from several mines in the eastern half of the Little Maria Mountains gypsum belt (68), and the company owns gypsum deposits in the Maria Mountains also. The second producer, the Utah Construction Company, produced agricultural gypsum. The mine is on the west side of the Little Maria Mountains; and the grinding plant and shipping point was at Inca Siding, a station 5 miles south of Midland. Most of the description that follows is based on studies of the Garbutt and Orcutt property (64), the deposit that was worked by the Utah Construction Company. The area mapped (pls. 2, 3) is immediately west of the principal United States Gypsum Company workings.

The American Gypsum Company leased the Garbutt and Orcutt property[6] (64) which consists of five claims located in secs. 2, 10 and 11, T. 4 S., R. 20 E., SBM. These claims were patented about 1920. The deposit was explored by diamond drilling in 1945, and mining began in 1947. The Utah Construction Company was engaged to do the work, and

[4] Miller, W. J., Geology of the Palm Springs-Blythe strip, Riverside County, California: California Div. Mines Rept. 40, p. 25, 1944.
[5] Miller, W. J., op. cit., p. 28.
[6] Tucker, W. B., and Sampson, R. J., Riverside County: California Div. Mines and Mining Rept. 25, p. 510, 1929.

in 1948 this company acquired an interest in the property. It was closed in June 1950.

Workings consist of an open pit in which disconnected benches at two levels have been developed. Broken gypsum was crushed in a primary jaw crusher at the quarry and trucked over an improved gravel road 7 miles long to the grinding plant at Inca Siding. The product was guaranteed to contain 93 percent gypsum. The operation is described in another section of this study.

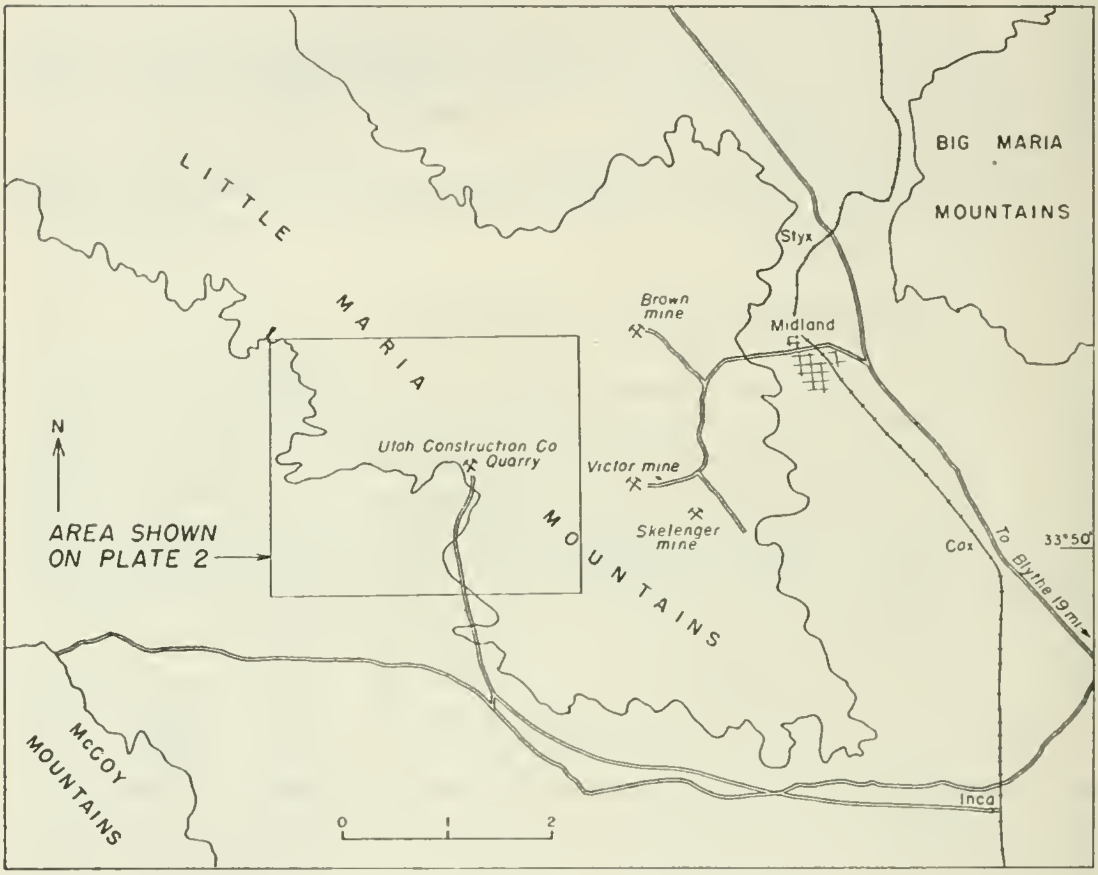


FIGURE 1. Index map showing locations of gypsum mines in the Little Maria Mountains.

Stratigraphy

No geologic description of the Little Maria Mountains is known to the author, and very little has been published on the geology of the gypsum deposits. Surr [7] has prepared a cross section through the central part of the gypsum belt, and Miller [8] has described briefly similar gypsum beds, probably an extension of the Little Maria Mountains deposit, 10 miles south and east of the area under consideration. Miller designated these beds the Maria formation of probable Paleozoic age.

The rocks of the gypsum belt are crystalline limestone, quartzite, and green schistose rocks, that in general strike N. 70° E. across the range and occupy a low pass. The sediments are bordered on the south by granite and gneiss that extend to the tip of the range; to the north granitic rocks extend for about 2 miles, and limestone lies beyond.

[7] Surr, Gordon, Gypsum in the Maria Mountains of California: The Mining World, vol. 34, pp. 787-790, April 15, 1911.
[8] Miller, W. J., Geology of the Palm Springs-Blythe strip: California Div. Mines Rept. 40, pp. 25-28, 1944.

The deposit has been "commonly considered" [9] to be of pre-Cambrian age. Miller,[10] who mapped part of the Maria Mountains 10 miles to the east, found crinoid fragments in similar rocks and states that their age is post-Cambrian, perhaps Silurian. The writer found no fossils in the area described nor any other indication of the age of the rocks.

Green Schistose Rocks. The central part of the gypsum belt is occupied by green colored feldspathic quartzite and schist. Several recognizable types occur in bands several hundred feet wide that may represent original bedding. Most of the material is well-foliated, and the foliation is parallel to the bedding of adjacent rocks. Much of the schistose rock is a greenish-gray, fine- to medium-grained feldspathic quartzite that when weathered has a granular appearance. Quartz and albite form a ground mass with xenoblastic texture in which the average grain diameter is 0.02 inch. Some of the albite grains are as much as three times the average size. Epidote, biotite, and tremolite are concentrated in sub-parallel streaks. Epidote forms granular aggregates arranged in layers parallel to flakes of biotite. Tremolite occurs as tiny needles, both in aggregates and as individuals in albite grains.

Another type of feldspathic quartzite, usually found close to gypsum, is of much finer grain and breaks into sharp-edged, blocky fragments. In thin section it resembles the granular quartzite except that the proportion of epidote, tremolite, and biotite to quartz and albite is smaller in the blocky quartzite.

A third type is a green-colored gypsiferous schist. Throughout the central area of green schistose rocks are bands and patches of soft gypsiferous soil, but without exception the underlying rock, wherever exposed by trenching, is a thinly laminated schist with no visible gypsum. The microscope reveals that the gypsiferous schist is much like the feldspathic quartzites except that gypsum comprises about 15 percent of the xenoblastic ground mass. Biotite, epidote, and tremolite together comprise about 30 percent of the rock.

Limestone. Flanking the central area of green schistose rocks on both sides of the gypsum belt is 700 to 900 feet of limestone with interbedded gypsum zones. The gypsum bodies are described below. Most of the limestone is a tough, unfractured, fine-grained crystalline limestone that is nearly white when fresh but buff-colored on weathered surfaces. Where these beds are steeply dipping they rise in wall-like, talus-flanked ridges as much as 100 feet above the general level of adjacent rocks.

The contact of the limestone with the green schistose rocks is irregular in detail, and the limestone close to it contains tremolite. The tremolitic limestone is of a golden brown color, and glassy tremolite prisms as much as $\frac{1}{10}$ inch long that are oriented in a plane parallel to the foliation give the rock a micalike sparkle. There are bands of feldspathic quartzite and schist on the limestone side of the contact and irregular pods of tremolitic limestone within the schistose rocks. Gypsum bodies, some of mineable width, occur on both sides of the contact.

In contrast with the buff limestone are beds of a dark-weathering limestone that contain streaks and blebs of silica. Several foliation planes

[9] Moore, B. N., Gypsum, in Mineral resources of the region around Boulder Dam: U. S. Geol. Survey, Bull. 871, p. 166, 1936.
[10] Miller, W. J., op. cit., p. 28.

give the rock a splintered appearance. This siliceous limestone may be traced across the entire area mapped on the north side of the gypsum belt, and is prominent on the south side also.

Quartzite. Beyond the buff limestone that contains the gypsum zones the sequence of the rocks on the north side of the gypsum belt is completely different from that on the south side. On the north the limestone is overlain by five to six hundred feet of tan-white quartzite. The quartzite is faintly banded, and is so brecciated that sound pieces greater than a foot in diameter are uncommon. Quartz in equidimensional interlocking grains makes up 90 percent of the rock, while albite and sparsely distributed flakes of biotite complete the mineral assembly. The quartzite forms smooth talus-covered slopes, and exposures are not common.

North Limestone. The quartzite grades on the north into one to two thousand feet of fine-grained crystalline limestone containing some beds of quartzite as much as 50 feet thick. The limestone is tan when fresh, but weathered surfaces are dark brown. This unit has been brecciated, and the limestone members but not the quartzite members have been recemented with calcite. Many specimens of all kinds of limestone described were tested with acid, but none were dolomitic.

North Granite. The northern limit of the gypsum belt is a nearly vertical fault along which the north limestone is in contact with a granitic body that extends northward for at least 2 miles. Although not enough specimens were examined to determine the composition of this body, one specimen selected at random is quartz monzonite. Average grain size is about $\frac{1}{10}$ inch. It is composed of quartz, 35 percent; microcline, 25 percent; oligoclase, 25 percent; and biotite, 5 percent. Biotite is in the form of clusters of small crystals. Many of the feldspar grains, especially oligoclase, have been replaced by sericite and by epidote.

South Granite. The ridge south of the gypsum belt is composed of coarse-grained gneissic granite that is quite different from the granite to the north. Foliation is pronounced on weathered surfaces but not evident in the fresh rock. The rock is characterized by lavender-colored phenocrysts of microcline and albite feldspar up to $\frac{1}{3}$ inch long. There are quartz grains almost as large as the feldspars, some biotite, and a minor proportion of sphene and magnetite. The albite crystals have been largely replaced with sericite, epidote, and calcite.

Undifferentiated Metamorphic Rocks. The relations between the south granite and the gypsum belt are not clear. Between the granite and the buff limestone containing the gypsum zones are feldspathic quarzites and gneisses that have not been differentiated in mapping. The foliation of the metamorphic rocks seems to conform with both the foliation of the south granite and the bedding of the limestone. Light-colored quartzite close to the limestone contains porphyroclasts of quartz and microcline 0.1 inch in size. Toward the granite the quartzite becomes darker, contains more biotite, and grades into gneiss with abundant large porphyroclasts that have been elongated and crushed.

Possible Dikes. The only igneous rock found besides the granites was a thin body of altered andesite that occurs in tremolitic limestone between

WESTERN PART OF GYPSUM BELT

Little Maria Mountains, Riverside County. View southeast from the north limestone. Green schistose rocks lie in the center, and the south granite forms the ridge in the background. The Utah Construction Company quarry is at the right edge of the picture.

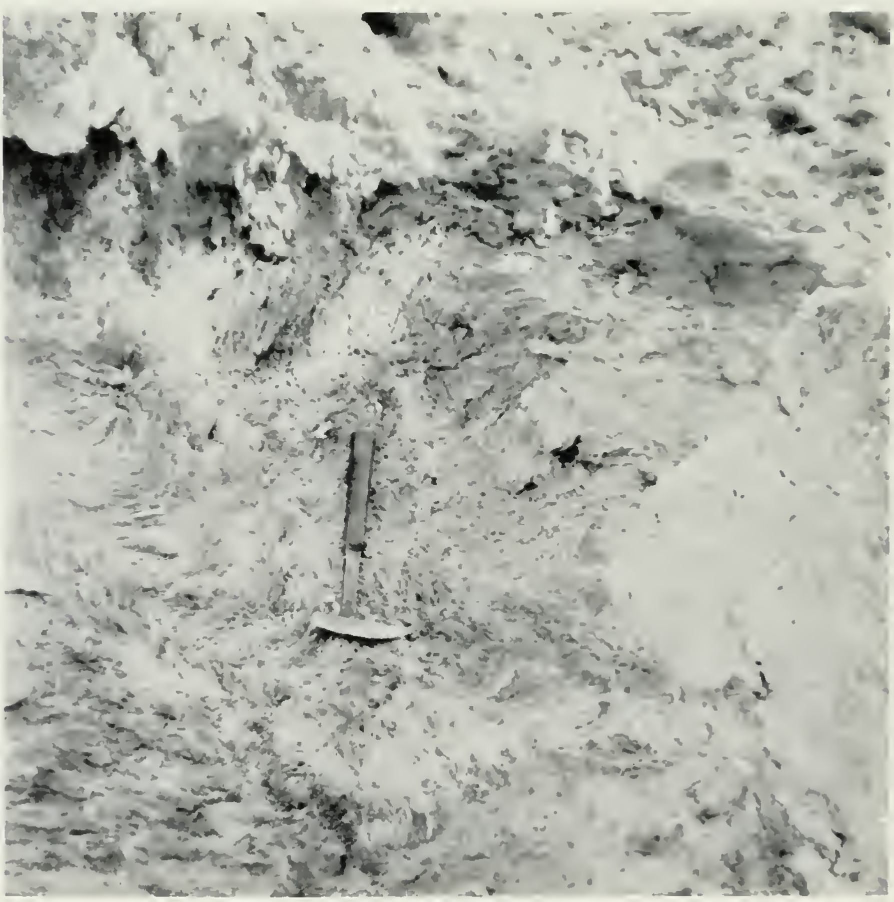
NORTH SIDE OF GYPSUM BELT

Little Maria Mountains. The high peak is the north limestone and the smooth lower slopes are quartzite. The north granite is visible at the head of the canyon.

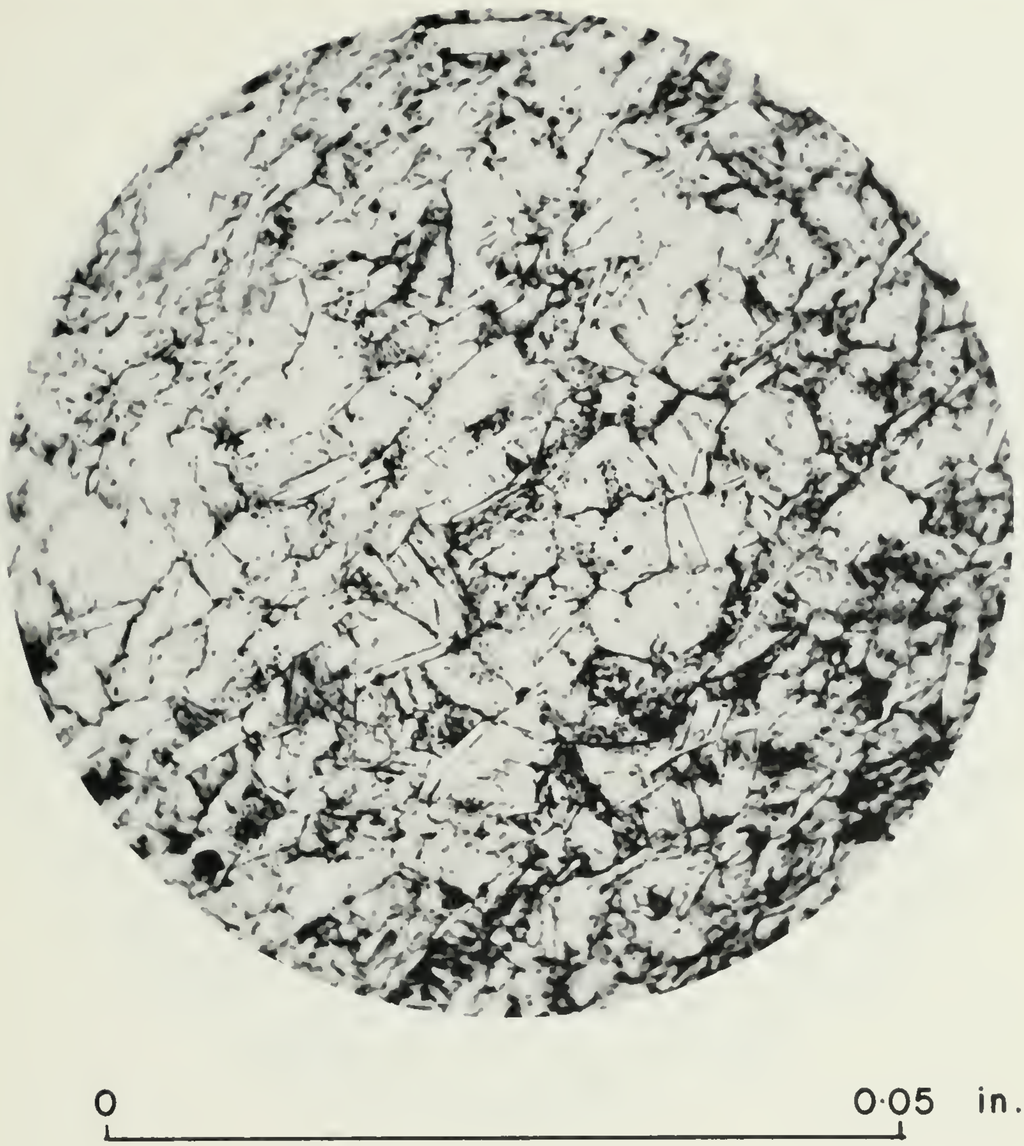
VIEW FROM NORTH SIDE OF GYPSUM BELT

Little Maria Mountains, S. 45° W. from the north limestone. Limestone reefs are prominent in the lower right. In the lower left is the Utah Construction Company quarry. The McCoy Range is the high ridge on the sky line.

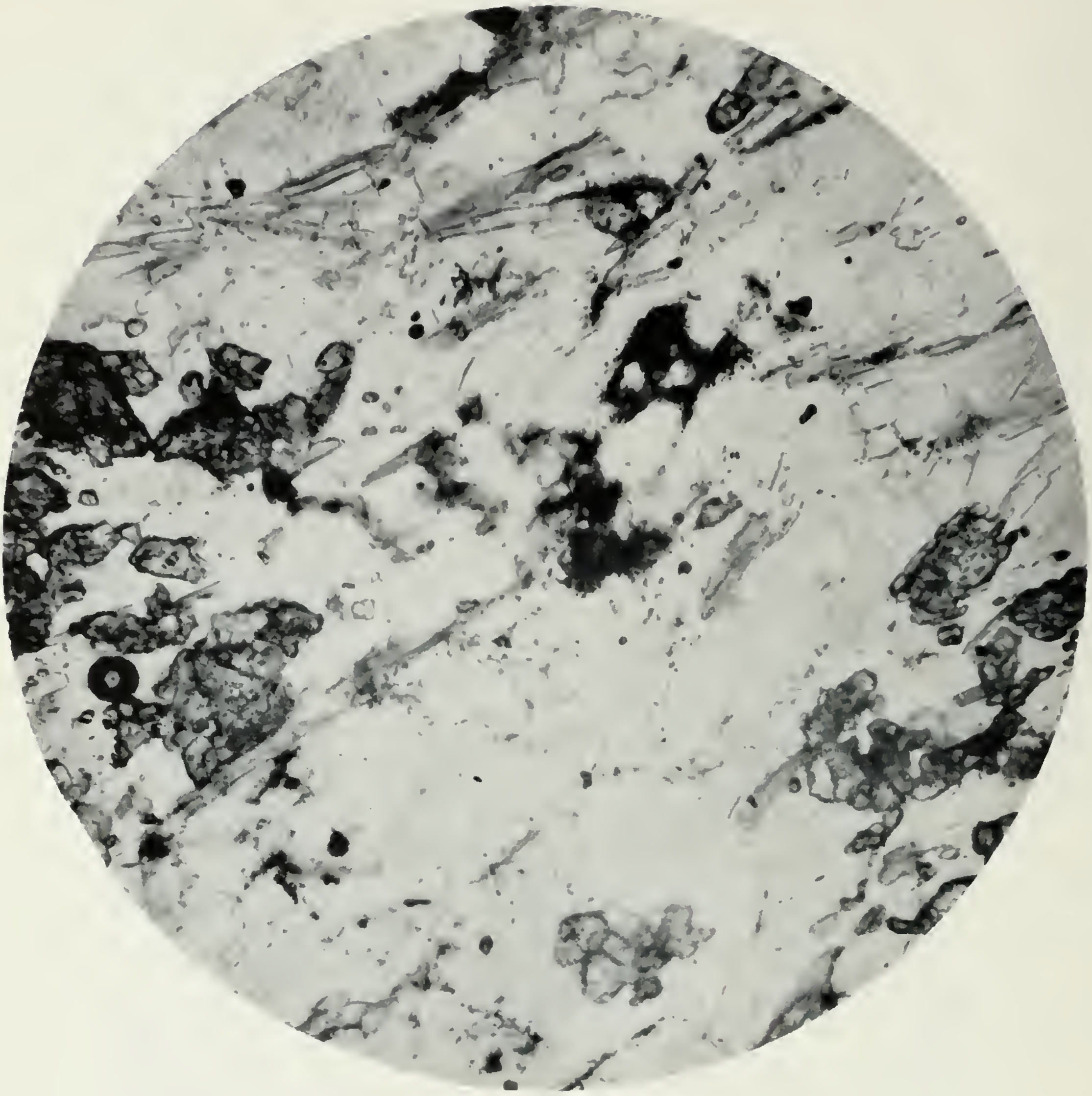
A. SILICEOUS LIMESTONE
Little Maria Mountains. View along strike from the wash that flows west of the Utah Construction Company quarry.



B. CRUMPLED GYPSIFEROUS SCHIST
Little Maria Mountains. Crumpled gypsiferous schist, Little Maria Mountains. Gypsum soil that covers the schist appears at the top of the photograph.



PHOTOMICROGRAPH OF TREMOLITIC LIMESTONE
Little Maria Mountains. Field consists of gray calcite and white tremolite.
Plain light.

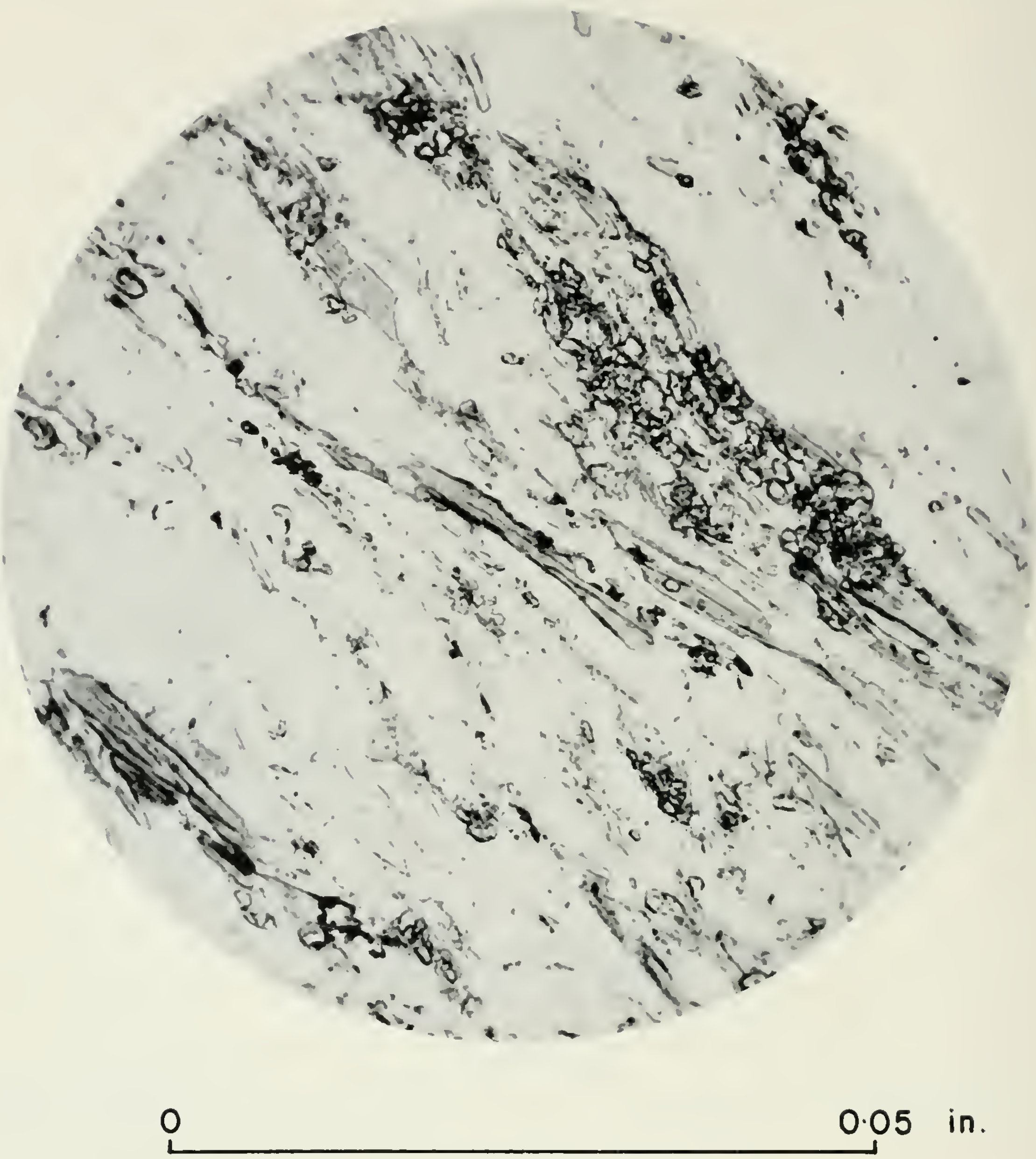


0 0·05 in.

PHOTOMICROGRAPH OF GYPSIFEROUS SCHIST, PLAIN LIGHT

Little Maria Mountains. Fibrous gypsum, quartz, and albite form a groundmass in which clusters of epidote crystals and roughly oriented flakes of biotite are imperfectly segregated into bands.

PHOTOMICROGRAPH OF GYPSIFEROUS SCHIST, CROSSED NICOLS



PHOTOMICROGRAPH OF NON-GYPSIFEROUS GREEN SCHISTOSE ROCK
Little Maria Mountains. Biotite, epidote, and tremolite (needles) in a granoblastic groundmass of quartz and albite. Plain light.

gypsum zones in the southern part of the gypsum belt. It is less than 10 feet thick and can be traced for only two or three hundred feet. It is composed of dark green, fine-grained rock that contains large lathlike grains of hornblende in a finer grained matrix of biotite and oligoclase. Chlorite is present—especially bordering hornblende grains—and there are scattered anhedral grains of epidote.

Gypsum Bodies. Gypsum with other rocks occurs interbedded with buff limestone in zones up to 100 feet thick that may be traced for several thousand yards and as less persistent, more lenslike bodies in the green schistose rocks close to the limestone contact. Gypsum bodies, except where they are exposed in cut banks or in artificial openings, are concealed by a distinctive light-colored soft soil that forms rounded, puffy-looking hills and slopes. The relatively few exposures indicate that although gypsum bodies as a whole are simple, yet they are complex in detail. Gypsum, wherever exposed, is much the same and has similar associations whether the body be in limestone or in schistose rock.

Commonly less than half of a gypsum body is gypsum, sometimes in beds 5 or 10 feet thick but more often a foot thick or less. Interlayered with these beds may be a variety of materials. Green-colored schist is almost always present, and quartzite may be found. Tremolitic limestone is common. White fine-grained sugary limestone is sometimes interbedded with gypsum. Some specimens of sugary limestone contain disseminated anhedral gypsum grains, and some contain tremolite but less than the brown tremolitic limestone described above. Chemical tests show that some of the sugary limestone is dolomitic.

The gypsum itself is a coarse-grained aggregate of flaky, transparent crystals up to $\frac{1}{10}$ inch in diameter. One specimen consists of large euhedral to subhedral rectangular gypsum crystals ranging from 0.10 x 0.03 inch to 0.01 x 0.005 inch in size in a much finer grained matrix of intricately interlocking gypsum grains. Although there are beds of pure gypsum 10 feet or more thick, much of it contains impurities. Gypsum grades into schist, and some impure gypsum contains as much as 20 per cent calcite. Similarly there are gradations between schist and tremolitic limestone. The best exposures are in the mine of the Utah Construction Company which is described below.

Anhydrite, although not plentiful, has been found in the deepest part of the Utah Construction Company quarry. Anhydrite in place was not seen, but it occurs abundantly in the neighboring mines of the United States Gypsum Company where it is believed to be the immediate source of the gypsum. The anhydrite is a white material with a faint bluish tinge most of which is the mineral anhydrite in grains 0.02 inch up to 0.20 inch in size. A majority of the grains have polysynthetic twinning, many in two directions. In the single specimen examined under the microscope gypsum comprises 15 per cent of the total. Gypsum fills cracks 0.005 to 0.05 inch wide that follow anhydrite grain boundaries. Some anhydrite grains that are completely surrounded by gypsum have the shape of the anhydrite cleavage. All of the gypsum has a fibrous texture. Some of the wider gypsum veinlets are composed of grains in which the fibers are imperfectly aligned; such grains have the same shape as the anhydrite grains.

Structure

The rocks of the gypsum belt have an average strike of N 70° E and dip northwest at angles that increase from 60° at the south side to vertical in the buff limestone on the north side. Farther north the dip decreases to about 60° NW at the bounding fault. The presence of gypsum zones and limestone beds on opposite sides of the central green schistose rocks suggests that the entire gypsum belt may be an anticline overturned and crowded against the north granite. Inconclusive evidence that the axis passes through the central area is given by the prevailing westerly dip of the green schistose rocks and by the attitudes of some outlying outcrops of limestone and gypsum southwest of the quarry. It is to be noted, however, that the succession of rocks on the south side of the gypsum belt is not exactly the same as on the north side. In particular, on the south side there is no great thickness of quartzite nor is there a counterpart to the limestone found between the quartzite and the north granite. It is probable that the gypsum belt contains two groups of gypsum zones that are similar but not identical.

Faulting is present but is relatively minor. The most prominent fault is the nearly vertical one that separates the north granite from the limestone. The fault, which is exposed in the larger canyons north of the Utah Construction Company quarry, is a single sharp break nearly free of gouge. A second fault, or probably fault zone, runs transversely to the regional strike 3000 feet east of the Utah Construction Company mine. Although its surface is nowhere exposed, the fault has offset the limestone beds one to two hundred feet. There is no evidence of this fault in the green schistose rocks. There are in addition other smaller transverse faults that cut the limestone beds.

The Utah Construction Company Quarry (64)

The quarry of the Utah Construction Company is on a hill surrounded by alluvium. Thick gypsum beds associated with schist are exposed here, but they are not readily recognizable beyond the alluvium. Probably they are a comparatively local concentration of gypsum on the schist side of the contact of the limestone with the green schistose rocks.

The mine workings (fig. 2) have encountered several thick layers of gypsum with interbedded schist. The gypsum is the typically coarse-grained material of high purity characteristic of the Little Maria Mountains area. No great quantity of granular green feldspathic quartzite occurs in the quarry, although there is some of the fine-grained, blocky feldspathic quartzite. Most of the schist in the quarry is a bluish-gray quartz-biotite schist that contains much less epidote and tremolite than the granular feldspathic quartzite. The biotite schist found in the quarry contains about 15 percent gypsum in the form of fibrous, slightly elongate grains interlocked with the quartz grains. Perpendicular to the plane of the bedding gypsum is in comparatively sharp contact with schist, but along the strike it grades into gypsum containing small schist lenses or disseminated flakes of a green micaceous mineral.

One specimen of mixed gypsum and schist consists of gypsum mixed with a minor amount of calcite in the form of lenses up to 3 inches in diameter and half an inch thick separated by schistose layers up to a quarter of an inch thick containing biotite, muscovite, and tremolite.

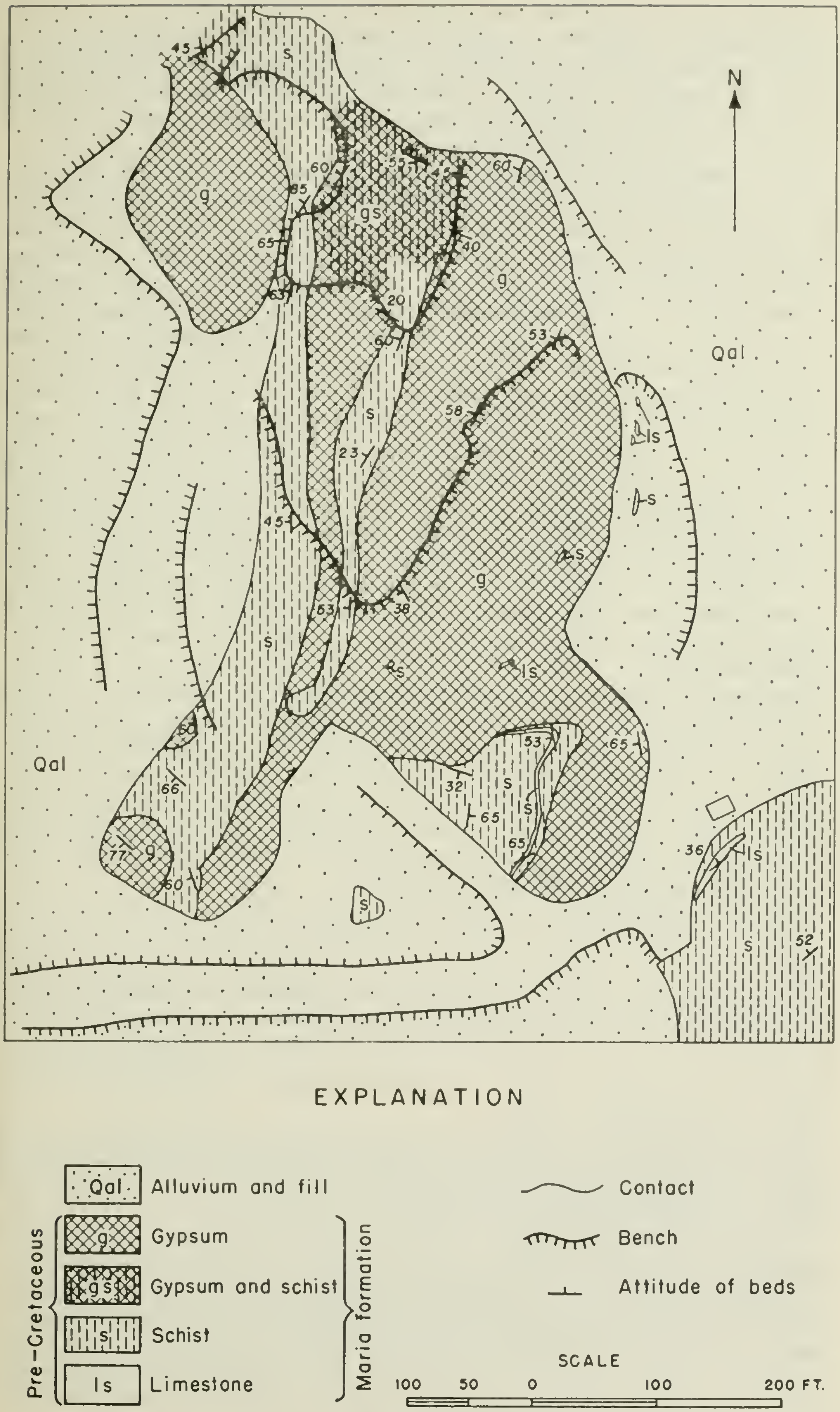


FIGURE 2. Geologic map of the Utah Construction Company quarry, Little Maria Mountains.

These layers of impurities are curved around the gypsum lenses. Some of the gypsum contains streaks of brownish calcite. A thin section of such a specimen contains about 20 percent calcite in the form of anhedral grains intricately interlocked with fibrous gypsum grains. Tremolitic limestone occurs in the quarry, but it is almost entirely restricted to a 5-foot bed in the southeastern part.

The average trend of these alternating gypsum and schist layers is N. 25° E. with a dip of about 60° NW. The strike in the quarry is thus noticeably more northerly than the average of the Little Maria Mountains gypsum belt. Locally there is a wide departure from the average trend in two parts of the quarry. In the southeastern part and north of the crusher a mound of waste has been left unmined. The structure here is a syncline plunging to the southwest. In the southwestern part there is a nose projecting into the alluvium that may be a plunging anticline.

The quarry can be divided into several parts geologically. Immediately southeast of the quarry is a hill of granular green feldspathic quartzite and gypsiferous green schist similar to that which occupies the central part of the gypsum belt beyond the alluvium to the east. Close to its base on the northwest side there is a pod of tremolitic limestone that grades into green schistose rock. The contact between the rocks of this hill and the gypsum in the quarry is concealed by fill. In the southeastern part of the quarry is the synclinal mound mentioned above. Gypsum that occurs around the flanks dips beneath a core of blocky green quartzite. A bed of tremolitic limestone occurs in the quartzite close to the quartzite-gypsum contact.

The central part of the quarry lies between the synclinal mound and a bed of biotite schist. Most of it is in gypsum, but there are a few small, scattered lenses of both schist and tremolitic limestone. Along the east side of the quarry the gypsum was followed as much as 15 feet below the alluvium, and it was reported that limestone was encountered in the northern part of this excavation. Along the middle bench, where there are good exposures, the gypsum contains a number of layers of mixed gypsum and schist similar to those described above.

Farther northwest and lying between thick schist layers is a bed of gypsum from 20 to 60 feet wide. Where it crossed the lower bench it is quite narrow, but it widens northward. In the face of the upper bench there is a 60-foot thickness of nearly pure gypsum between schist layers that dip 60° NW. On the top of the bench, however, gypsum exists only as lenticular bodies three feet thick or less mixed with gypsiferous schist. Probably the gypsum grades into schist along the strike, and it may plunge northeastward also.

The southwest nose consists of mixed gypsum and schist with a little tremolitic limestone in which the proportion of gypsum ranges up to 75 percent. Attitudes of some lenses depart widely from the average of the quarry and suggest that the nose may be anticlinal.

Along the northwest side of the quarry gypsum originally bordered the wash. It has, however, been mined; the excavation has been filled.

Schistose rocks occur north of the quarry, and in the northeastern part of the island hill, where the quarry is located, there is limestone that dips beneath the schistose rocks. The trend of gypsum in the central part of the quarry indicates that its extension lies beneath the alluvium southeast of the northern part of the hill, but beyond the alluvium there are no comparable gypsum bodies.

Palen Mountains Deposits, Riverside County (69)

A large deposit of gypsum associated with pre-Tertiary meta-sedimentary and meta-igneous rocks exists in the Palen Mountains in sections 2, 3, 4, 9, 10, and 11, T. 3 S., R. 18 E., SBM. The gypsum occurs just south of Granite (Palen) Pass, a low pediment pass of comparatively moderate relief that separates the Palen Mountains to the south from the Granite Mountains to the north. The pass is 1½ miles wide and 3 miles long. The deposit lies 20 miles northwest of Blythe and 30 miles northeast of Desert Center, while the nearest railroad is 15 miles northeast at Rice, a station on the Santa Fe's Parker branch. The best approach is from the Desert Center-Vidal highway, from which 16.7 miles from Desert Center, a road turns eastward toward Granite Pass. This seldom-traveled road is, however, likely to be covered with dune sand.

Operations have been restricted to surface exploration and development work. Diamond drilling or other subsurface exploration has not been undertaken. Extensive claims were patented 20 to 30 years ago by John Webb and George Pepperdine, and in 1949 John Webb and Fleetwood Lawton carried out some additional development.

The following geologic summary of the deposits is based largely on studies of R. A. Hoppin,[11] made primarily to reveal the internal structure and petrology likely to be found in the mountain ranges of the Basin—Ranges geomorphic province. E. C. Harder [12] made a reconnaissance of the area in 1909 and described the gypsum deposits in general terms.

Although the geology of the region is complex, the broader features are relatively simple. The gypsum occurs in a series of meta-sediments that includes marbles, quartzites, and thermal metamorphic derivatives of them. Hoppin has correlated this gypsum-bearing series with the Maria formation of Miller [13] on the basis of lithology. North of these meta-sediments lie the granitic rocks of the Granite Mountains, and to the south are meta-sediments that have been tentatively assigned to the McCoy Mountains formation.[14] In the area under consideration a sill-like body of meta-igneous rock has intruded the gypsum-bearing series. The meta-sediments and meta-igneous rocks are arranged roughly in bands that trend east-west across the range and dip predominantly to the north at moderate angles. Five principal bands are distinguishable, which from north to south are as follows:

1) Meta-sediments, principally in the northwest part of the area.
2) Meta-igneous rock, extending about two-thirds of the way across the range from west to east.
3) Meta-sediments.
4) Porphyroblastic meta-igneous rock.
5) Meta-sediments.

Gypsum in quantities large enough to be of probable economic interest is found in three places. The southern gypsum-bearing series is in the eastern end of band five, the northeastern gypsum-bearing series is in the eastern end of band three, while the northwestern gypsum-bearing

[11] Hoppin, R. A., The geology of the Palen Mountains gypsum deposit, Riverside County, California: Division of the Geological Sciences, California Institute of Technology, Contribution No. 580, June 1951 (unpublished).

[12] Harder, E. C., The gypsum deposits of the Palen Mountains, Riverside County, California: U. S. Geol. Survey, Bull. 430, pp. 407-416, 1910.

[13] Miller, W. J., Geology of the Palm Springs-Blythe strip, Riverside County, California: California Div. Mines, Rept. 40, p. 25, 1944.

[14] Miller, W. J., op. cit., p. 32.

series is in band one. Each differs from the others in stratigraphic succession and is separated from the others by meta-igneous rocks. It is assumed that the three are separate units of the gypsum-bearing series. The following table summarizes the geologic history of the area.

1) Deposition of the gypsum-bearing series.
2) Deep burial followed by the onset of stresses resulting in the regional metamorphism of the sediments.
3) Intense cataclastic deformation, including folding, faulting, brecciation, and crushing.
4) Erosion followed by deposition and burial of McCoy Mountains (?) formation.
5) Intrusion of quartz diorite.
6) Faulting and regional metamorphism—less severe than in (2).
7) Intense metasomatic activity including felspathization and recrystallization followed by intrusion of aplites and pegmatites, and finally by hydrothermal veins.
8) Erosion: deposition of Tertiary (?) or Pleistocene gravels, probably some faulting.
9) Small-scale normal and reverse faulting.
10) Deposition of gravels.
11) Faulting of recent gravels.

Deformation has been profound. The results of folding, faulting, crushing, brecciation, shearing, and jointing are apparent and range downward in size to the microscopic. Almost all contacts are fault contacts. The most intense deformation occurred before the intrusion of the igneous rocks, but the igneous rocks themselves have been notably deformed.

The igneous body was intrdued as an irregular sill. The south contact, although modified by faulting, is fairly regular; but the north or hanging wall contact is complex. Irregular apophyses 1 foot or 2 feet in diameter and ramifying dikes and sills an inch thick or less cut the meta-sediments, and within the large meta-igneous masses are to be found small, scattered patches of the meta-sediments. In general the structure is more complex in the western part of the area than in the eastern. A large area in the western part of band three was not differentiated in mapping, and the western two-thirds of band five was mapped as undifferentiated meta-sediments.

Gypsum occurs in massive beds of high purity up to 100 feet thick that are interbedded with marble and quartzites. Not only do the gypsum beds change quickly in thickness along the strike, but they contain isolated blocks and lenses of marble ranging up to several tens of feet thick. Less common impurities are quartzite and fine-grained green schist containing epidote, green biotite, chlorite, and quartz that may form thin green films or occur as rock composed of alternating layers of gypsum and waste an inch or two thick.

The gypsum itself is a white aggregate of anhedral grains whose average size is 0.2 millimeter. The microscope reveals sparsely distributed grains of calcite and epidote. Little anhydrite occurs on the surface, and its presence at depth has not been ascertained.

The marbles are fine-grained rocks that are white to buff in color, or less commonly, pink, dark brown, or gray. Dolomitic marble was not found, although some of the marble that has been recrystallized by thermal metamorphism contains magnesium minerals. The effects of the intrusive body on the marble are discussed below.

Two principal types of quartzite are recognized. The first, consisting mainly of quartz with a minor amount of white mica and hematite, is

white or pink. The second is a green quartzite containing quartz, feldspar, epidote, and tremolite that shows preferred orientation. The quartzites occur as thick beds cut by closely spaced joints, as narrow partings in gypsiferous beds, and as laminated, incompetently folded calcareous quartzite alternating with marble. Closely associated with the quartzites are the grits, a group of rocks in which grains of feldspar and quartz 0.2 to 0.3 millimeter in size occur in a much finer matrix of these and other minerals. The grits grade into equigranular quartzite.

The meta-igneous rocks retain little of their original igneous textures. They are now strongly foliated, fine-grained biotite-epidote-albite-quartz schist. The chemical composition and the presence of relict andesine suggest that the intrusive may have been originally diorite or quartz diorite.

The effect of the intrusive on the gypsum is difficult to evaluate because no intrusive contacts are exposed. It is assumed that dehydration was the only effect. In the marbles, however, the intrusive produced skarns of garnet, epidote, and amphibole, and caused zones of recrystallization. Trending east-west across the area and lying directly above the meta-igneous sill are dense, fine-grained, white, lime-silicate rocks that form a series of sharp peaks. They are composed of calcite with subordinate amounts of wollastonite, diopside, and epidote.

A post-intrusion period of regional metamorphism is postulated because the meta-igneous rocks cut off all the folds and the major faults in the meta-sediments. It is suggested that the post-intrusion metamorphism was less severe than the pre-intrusion metamorphism.

The metasomatic and hydrothermal activity that followed the second period of regional metamorphism resulted primarily in the feldspathization of the meta-igneous rocks. The southern third of the intrusive body contains abundant feldspar porphyroblasts; and the porphyroblastic phase, although retaining its orientation, is granitic in appearance. Zones of incipient feldspathization are to be found within the non-porphyroblastic phase. The last stage of the mineralization is represented by veins and mineralized sheer zones that cut both the meta-sedimentary and meta-igneous rocks. Possibly the hydrothermal activity is associated with the emplacement of the granitic rocks of the Granite Mountains.

The gypsum, Hoppin believes, was originally formed through sedimentary processes of deposition. Although the relations of the gypsum to the enclosing marble and quartzite have been greatly modified by tectonic agencies, several areas suggest that the original sediments included zones in which thin limestone beds interfingered with thin gypsum beds. The absence of associated salt beds and the presence of interbedded gypsum and limestone suggests that the calcium sulfate precipitated from brine of comparatively low salinity. It is likely, therefore, that most of the calcium sulfate originally precipitated as gypsum.[15]

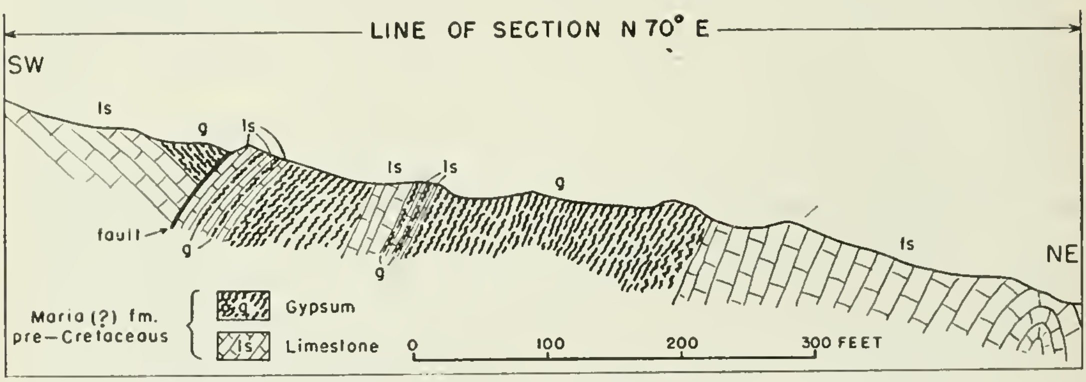
The sedimentary gypsum was converted to anhydrite during the pre-intrusion period of regional metamorphism. Heat is believed to be the controlling factor in the conversion of gypsum to anhydrite. Subsequent erosion has exposed the anhydrite and permitted gypsum to form again. The effect of the post-intrusion period of regional metamorphism is open to question, for Hoppin doubts that a sufficiently high temperature was attained to dehydrate the gypsum. The presence of deformation fabrics

[15] Posjnak, E., Deposition of calcium sulfate from sea water: Am. Jour. Sci., vol. 238, pp. 565, 566, 1940.

in the gypsum suggests that the gypsum itself has been deformed because it is doubtful that deformation fabrics in anhydrite could survive hydration and its accompanying volume change. The isolated marble blocks that occur in the gypsum apparently have been jostled about, and this fact further supports the theory that the calcium sulfate existed as gypsum during the deformation.

Riverside Mountains Deposits, Riverside County (70, 71)

A large deposit of pre-Tertiary gypsum occurs on the east face of the Riverside Mountains about four miles south of Vidal in the northwest corner of T. 2 S., R. 24 E., SBM. Part of the gypsum is in the Colorado Indian Reservation. Development work only consisting of short tunnels and test pits has been carried out. No road goes to the deposit. An abandoned road leaves U. S. Highway 95 four miles south of the San Bernardino County line and crosses the alluvial fan to an old camp at the mouth of the principal canyon along this part of the mountain front. A trail continues up the canyon. The principal gypsum deposit is on a south branch of the main canyon. Its mouth, which is very inconspicuous from the bottom of the main canyon, was marked in 1949 by two lengths of stove pipe strung on a pole. Relief is extreme, and the construction of a road would be difficult.



SECTION THROUGH THE RIVERSIDE MOUNTAINS DEPOSIT

FIGURE 3.

Gypsum occurs in a 100-foot zone that dips southwest at angles of 50° or greater and strikes northwestward. The zone is made up of coarsely crystalline white gypsum interbedded with brown-weathering crystalline limestone and red quartzite. Between the gypsum zone and the highway are quartz-biotite schist and several hundred feet of limestone. The gypsum crops out for at least half a mile. Lying on the hanging wall limestone is several hundred feet of gypsiferous green schist that has been briefly described by Noble.[16] The schist is cut by quartz veins, and it also contains a few lenses of crystalline gypsum up to an inch thick. Gypsite up to 10 feet thick covers the green schist.

Clark Mountain Area, San Bernardino County

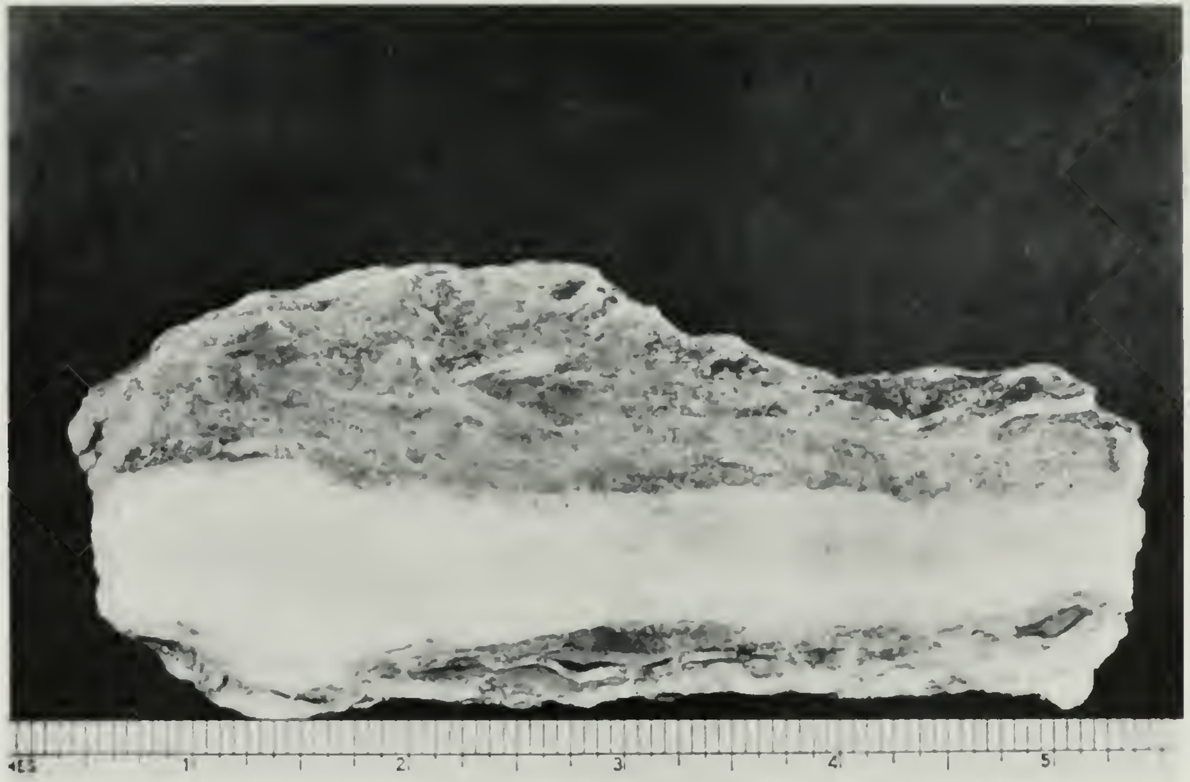
Undeveloped deposits of gypsum occur in the northeast corner of San Bernardino County, north of Clark Mountain at the south end of Mesquite Valley. They are associated with pre-Cretaceous sediments that, unlike those of the gypsum deposits of eastern Riverside County, are not noticeably metamorphosed.

[16] Noble, L. F., Nitrate deposits in southeastern California: U. S. Geol. Survey Bull. 820, pp. 49-52, 1931.

GYPSUM ZONE BORDERING WASH

Little Maria Mountains. View southwest. Gypsum together with tremolitic limestone, quartzite, and gypsiferous schist forms persistent zones up to 100 feet thick interbedded with buff limestone. Commonly less than half of a gypsum zone is gypsum in beds up to 5 or 10 feet thick. Both gypsum and gypsiferous rock are concealed beneath a distinctive light-colored soil that forms rounded, puffy-looking hills and slopes. At the left is a prospect tunnel used as a powder magazine.

SPECIMEN FROM SOUTH GRANITIC BODY
Little Maria Mountains. Some of the feldspar crystals are of large size.



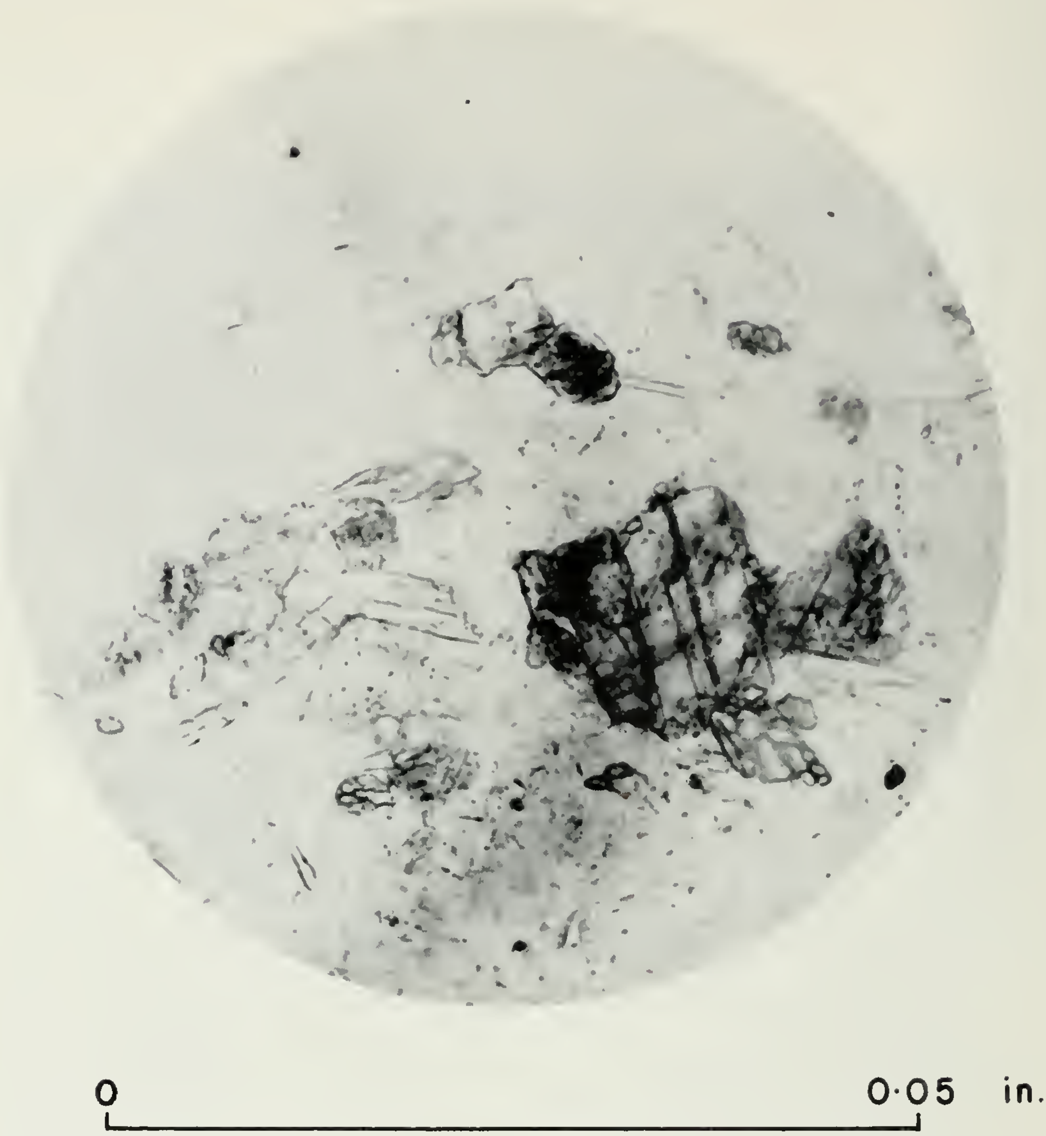
SPECIMEN OF FOLIATED GYPSUM AND SCHIST
Utah Construction Company quarry, Little Maria Mountains.

GYPSUM HILLS

Northeast of the Utah Construction Company quarry, Little Maria Mountains. Typical gypsum soil covers a jumbled mass of gypsum, gypsiferous schist, and tremolitic limestone.

UTAH CONSTRUCTION COMPANY QUARRY

Little Maria Mountains. View northwest. From 1947 to 1949 gypsum from this quarry was ground for agricultural use in a plant at Inca Siding. The gypsum occurs as lenticular bodies interbedded with schist and green feldspathic quartzite. The high ridge in the background is the north limestone; the smooth lower slopes are underlain by quartzite. A gypsum zone (illustrated in plate 12) borders the wash in the center of the picture.



PHOTOMICROGRAPH OF IMPURE GYPSUM
Containing calcite and tremolite, Little Maria Mountains. Plain light.

DETAIL OF SCHIST AND GYPSUM

Northwest corner of the Utah Construction Company quarry coarsely crystalline gypsum of high purity occurs as lenses 10 to 20 feet thick in bluish gray quartz-biotite schist containing epidote and tremolite.

DETAIL OF SCHIST AND GYPSUM

East bench of the Utah Construction Company quarry layers of mixed gypsum (light) and schist (dark). Some of the gypsiferous material contains as much as 20 percent calcite. The vertical cracks into which the hammer is stuck mark the location of a blast hole.

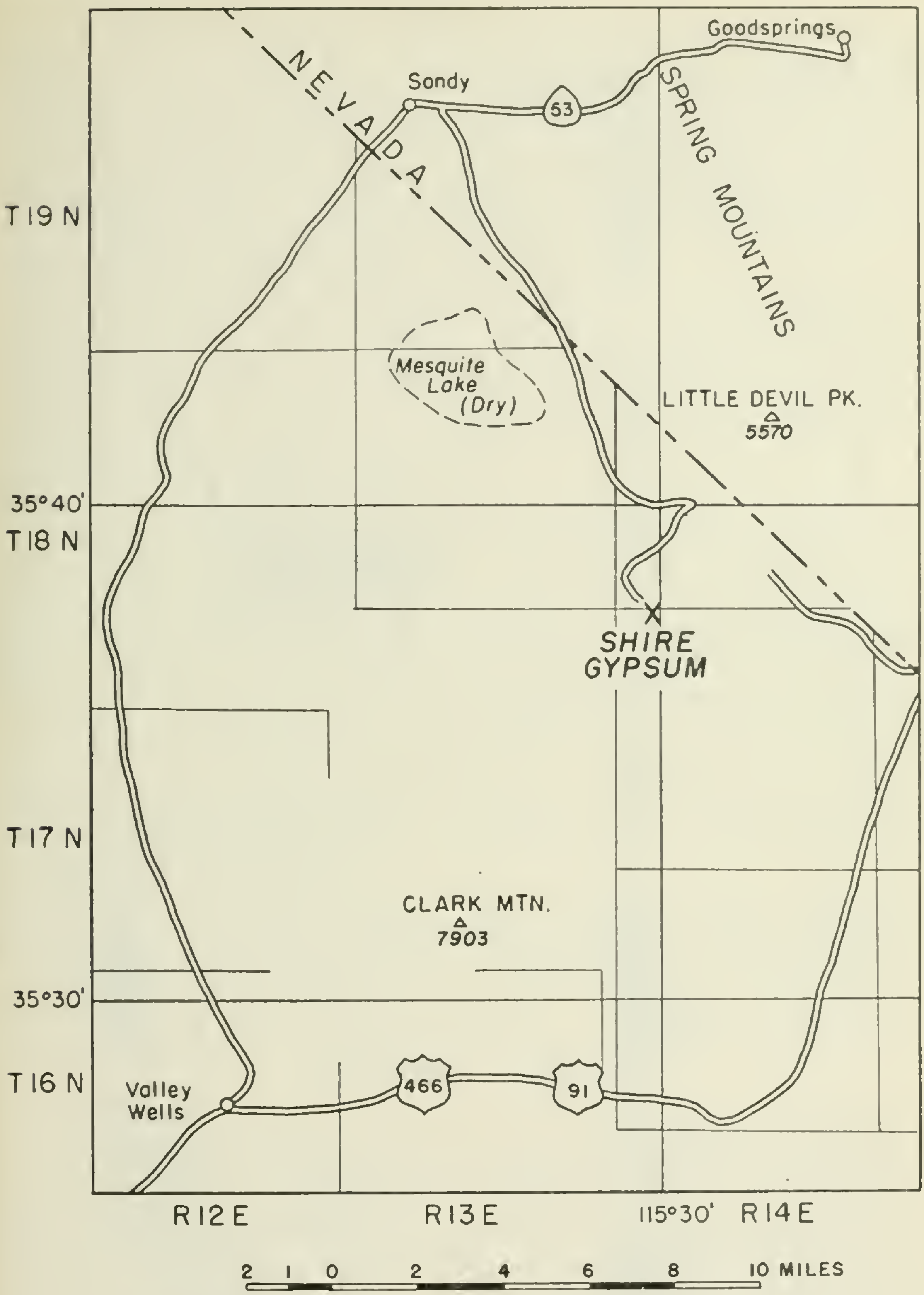


FIGURE 4. Index map showing location of Shire gypsum deposit.

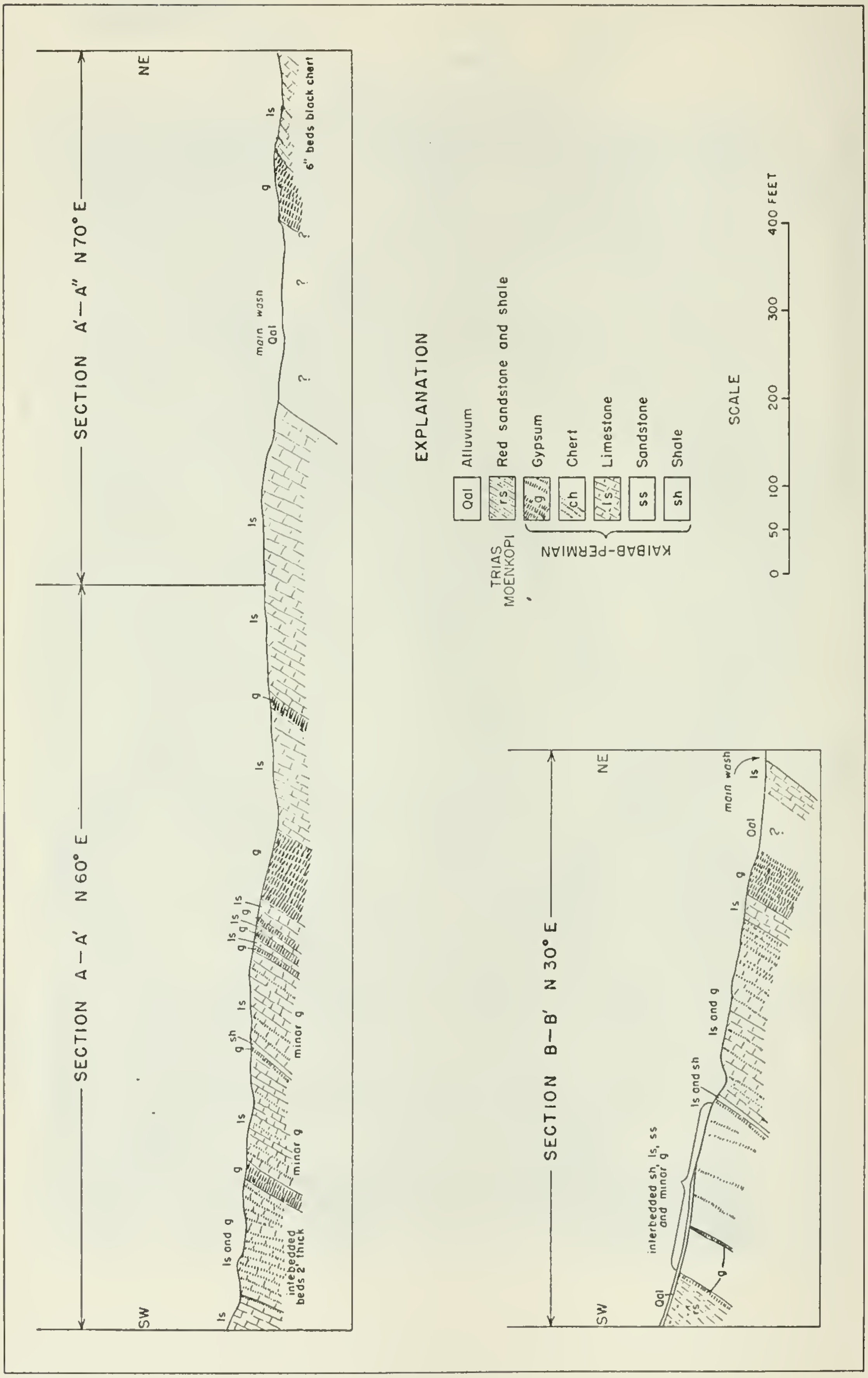


FIGURE 5. Geologic sections through Shire gypsum deposit.

Shire Deposit (87). D. H. Shire owns eight unpatented claims estimated to be in sec. 5, T. 17 N., R. 14 E., SBM. that were located in 1946. In 1951 the property could be reached from Sandy on the Valley Wells-Goodsprings road by following the old State Line Pass road for 11.2 miles southeast to the end of Mesquite Valley. A track passable for vehicles and marked by signs leads from the State Line Pass road to the property. The distance from U. S. Highway 91 and the Union Pacific Railroad via the State Line Pass road, which is washed out, is 12 to 13 miles. Assessment work only has been carried out on the property.

Two or more gypsum beds crop out for 1 to 2 miles along a large wash that trends about N. 40° W. Most of the gypsum is low on the talus-covered southwest side of the wash. Exposures of gypsum are scarce, although large areas of probable gypsum are covered by only from a few inches to a few feet of gravel. The deposit has been opened by a number of shallow trenches, but additional development work is needed to reveal fully the character of the deposit.

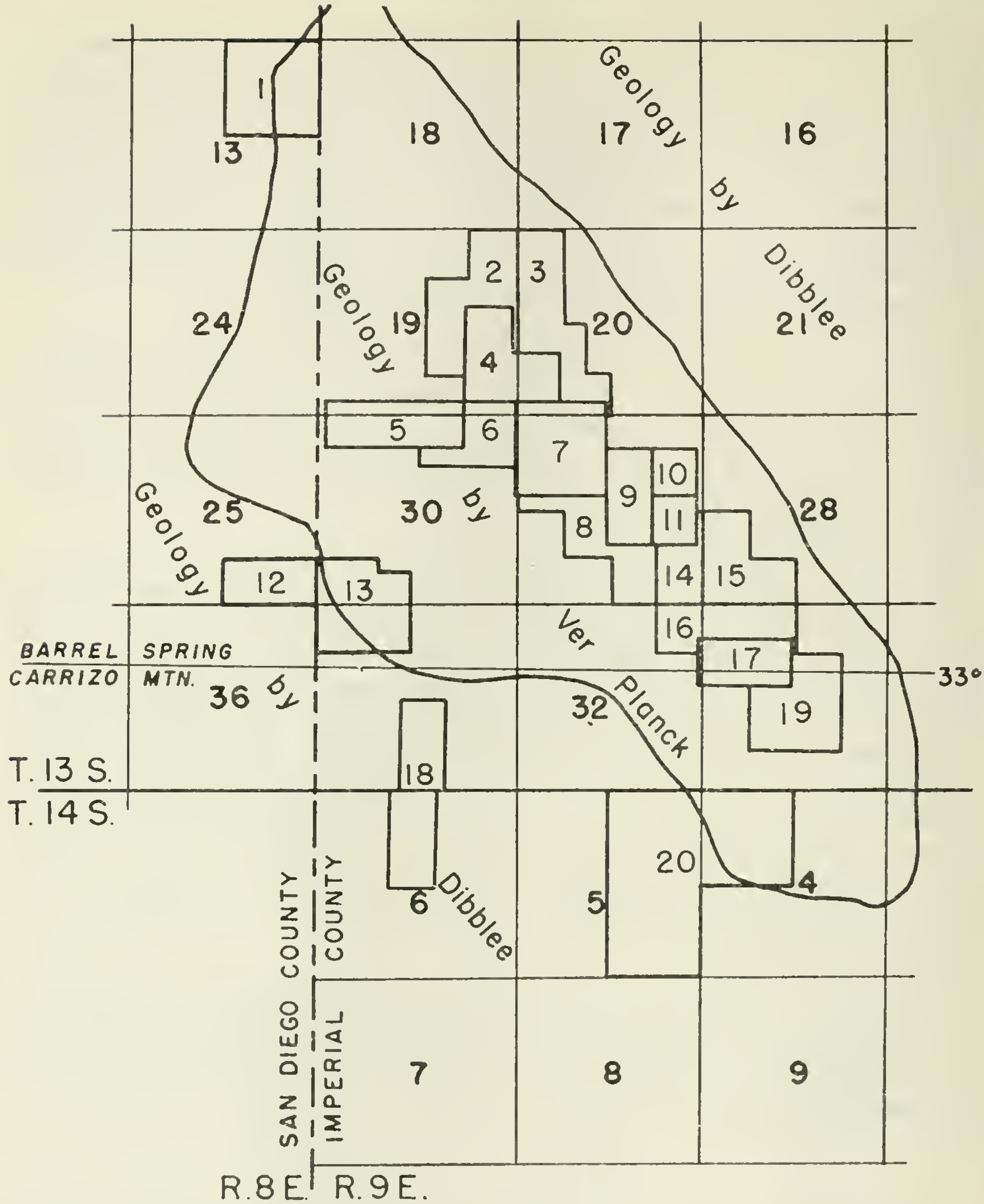
The general nature of the gypsum deposit is illustrated by the two large scale sections (fig. 5) that accompany this report. The gypsum-bearing beds strike about N. 40° W. parallel to the wash and dip about 50° SW. Beds of gypsum more than 50 feet thick occur with sediments that include black, thin-bedded, cherty limestone, tan-colored sandy limestone, and brown shale. The thickest gypsum beds occur close to the wash and quite possibly beneath the wash itself. Upward the proportion of gypsum to limestone and shale becomes increasingly less. The gypsum-bearing beds are members of the Kaibab formation of Permian age.[17] Overlying the gypsum-bearing beds are 100 to 300 feet of non-gypsiferous, red sandstone and shale of the Moenkopi formation (Triassic). The Kaibab beds and the Moenkopi beds are in contact with Paleozoic limestones along faults that parallel the wash.

The gypsum itself is a sugary white aggregate of glassy clear flaky crystals about 0.01 inch in diameter. Some of the gypsum contains streaks 0.1 inch thick and half an inch to an inch apart of brown earthy matter that contains calcite. Impure gypsum is to be found that consists of gypsum alternating with tan-colored sandy shale in irregular layers an inch to 2 inches thick.

TERTIARY DEPOSITS

Rock gypsum deposits of Tertiary age range in size from thin, discontinuous beds that are of no commercial interest except as a possible source of gypsite to bodies containing many thousands of tons of nearly pure gypsum. The largest gypsum mine in the state, the United States Gypsum Company Fish Creek Mountains operations, Imperial County, is in a Tertiary deposit. Other Tertiary deposits are to be found in the Upper Cuyama Valley region, Santa Barbara and Ventura Counties; in the Death Valley region, Inyo County; San Benito County; and in Miocene rocks of western Santa Barbara County. The California Tertiary deposits are typically enclosed in shale associated with coarse-grained non-marine sediments that have been mildly folded. The gypsum is a fine-grained, compact material that ranges from alabaster through dark gypsum to gypsiferous clay.

[17] Hewett, D. F., personal communication.



1. Edward B. Roberts et al
2. Hillcrest Placer *
3. Gypsum King Placer *
4. Tract 68 *
5. Tract 67
6. El Centro Placer *
7. Tract 69 *
8. Gypsum Queen Placer *
9. Tract 70 *
10. Tract 72
11. Tract 71
12. Sylvester Kipp
13. Blanc Placer
14. Swallow Placer No.2 *
15. Swallow Placer *
16. Regent Placer *
17. Tract 78 *
18. Blanc Placer No.3
19. South Pole Placer *
20. W.H. Waters

FIGURE 6. Index map showing locations of gypsum claims in the Fish Creek Mountains.

* Indicates United States gypsum claims.

Fish Creek Mountains Deposit, Imperial and San Diego Counties

The United States Gypsum Company owns 12 patented claims (23) near the northwest end of the Fish Creek Mountains that include parts of secs. 19, 20, 28, 29, 30, 32, and 33, T. 13 S., R. 9 E., SBM. The principal mining operations are in Tract 68 near the northwest end of the property. In addition the California Portland Cement Company owns Tract 67 (25) in SW$\frac{1}{4}$ sec. 19 and NW$\frac{1}{4}$ of sec. 30, T. 13 S., R. 9 E., the Blue Diamond Corporation owns Tract 71 (26) in SE$\frac{1}{4}$ NE$\frac{1}{4}$ and NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 29, T. 13 S., R. 9 E., and the National Gypsum Company owns deposits (90) in secs. 3, 5, and 9, T. 13 S., R. 8 E., SBM. The Roberts and Peeler strontium deposit (91) lies in sec. 13, T. 13 S., R. 8 E., SBM. northwest of the principal gypsum deposits. The strontium, which is associated with gypsum, was last worked by the Pan Chemical Company from 1940 to 1946.

The accompanying geologic map (pl. 20) covers an area in T. 13 and 14 S., R. 9 E., SBM. about 30 miles west of Brawley. The western boundary of Imperial County passes through the western part of the mapped area. The area may be reached over a secondary road from Scotty's Ocatilla on State Highway 78, 22 miles from its junction with U. S. Highway 99 and 3 miles west of the San Diego County line. This road, rough but passable for heavy equipment, runs southeastward for 9 miles to the United States Gypsum Company's quarry. In addition, a private narrow gage railroad runs to the United States Gypsum Company's calcining plant at Plaster City (29), about 25 miles to the south.

The area mapped includes the low northwestern end of the Fish Creek Mountains and extends westward to Fish Creek Canyon. Between the hills east of Fish Creek Canyon and the Fish Creek Mountains is a broad wash running S. 40° E. for about 4 miles from the northwest end of the Fish Creek Mountains. Gypsum crops out extensively on the hills bordering this wash, and large deposits of gypsum only partially explored lie outside of the wash and beyond the limits of the area mapped.

No detailed geologic descriptions of the area have been published, but T. W. Dibblee, Jr. has furnished the author with an unpublished geologic map of the Split Mountain area, scale 1/62500, prepared in 1944. In this report Dibblee's formation names have been adopted. Mining operations in the area have been described in reports of the California Division of Mines.[18]

Stratigraphy

The oldest rocks in the area are a pre-Tertiary complex that includes a series of metamorphic rocks intruded by plutonic bodies. The metamorphic rocks, which occupy perhaps half of the area mapped as basement, are in most places represented by a well-foliated, coarse-grained gneiss. In addition they include a body of coarse, blue-gray marble that was mapped separately and minor amounts of mica schist and quartzite. The structural trend of these rocks is N. 30° W. with dips of from 60° to 70° NE.

The most abundant of the plutonic rocks is a coarse-grained gneissic granite in which foliation is moderately well-developed. The approximate

[18] Sampson, R. J., and Tucker, W. B., Mineral resources of Imperial County: Calif. Div. of Mines Rept. 38, pp. 134-136, 143, 1942.
Tucker, W. B., Imperial County: California State Min. Bur. Rept. 22, pp. 270-275, 284, 1926.
Merrill, F. J. H., Imperial County: California State Min. Bur. Rept. 14, pp. 738-740, 1916.

composition is quartz 40 percent, orthoclase 40 percent, plagioclase 5 percent, biotite 15 percent, and a little chlorite. Grain size is from $\frac{1}{8}$ to $\frac{1}{4}$ inch. This granite is deeply weathered and in some areas, particularly in the northern part of the outcrop on the southwest side of the wash, it is stained red by oxidized iron minerals. The gneissic granite is cut by pegmatite dikes up to 6 inches thick that contain coarsely crystalline quartz and feldspar.

Associated with the granite is a plagioclase-biotite rock in which biotite flakes about 0.05 inch in diameter are oriented but not segregated into layers. Biotite makes up about 40 per cent of the rock, while the remainder is anhedral plagioclase, partly as grains the size of the biotite flakes and partly as grains up to a quarter of an inch in size. The plagioclase-biotite rock occurs as inclusions in the granite, in dikelike bodies cutting the granite, and as irregular bodies several hundred feet in diameter.

Split Mountain Formation. The Split Mountain formation of Miocene age is the oldest of the sedimentary rocks in the area and lies with depositional contact on the basement rocks. It is composed of poorly consolidated, terrestrial sandstone and very coarse-grained conglomerate. In the area mapped this formation may be divided conveniently into a lower member that is noticeably red and an upper member that is gray. The conglomerate beds strongly resemble the younger fans and can be distinguished from fans only by their topographic position.

The red member of the Split Mountain formation, which occurs only on the southwest side of the wash, is well exposed in Fish Creek Canyon and in the hills southwest of the wash. The base is exposed south of the principal gypsum body on the southwest side of the wash where sandstone lies with depositional contact on weathered granite. The lowest 50 feet of the Split Mountain formation is a porous, very poorly cemented arkose that is not red. Grains are well sorted and about an eighth of an inch in diameter. Quartz predominates, but weathered feldspar grains containing biotite flakes are present.

The remainder of the red member consists of red sandstone and conglomerate beds at least 850 feet thick. The sandstone, which is moderately well cemented by calcite and much less porous than the basal beds, is composed of angular, poorly sorted grains ranging from 0.1 to 0.5 inch in size. The red sandstone also is made mostly of quartz grains, but feldspar that is present forms many of the larger fragments. Biotite is present also. These beds are stained faintly red by oxidized iron minerals.

The lower part of the red member is predominantly sandstone containing a few thin lenses of conglomerate. By an increase in the number and thickness of these lenses the sandstone grades into a coarse-grained conglomerate of angular cobbles set in a shaly red matrix. The cobbles, which have an average maximum diameter of 3 feet and locally reach 10 feet or more in size, are composed of igneous and metamorphic rocks, principally gneiss and granite.

The gray member of the Split Mountain formation is predominantly a conglomerate like that in the red member except that it contains no red cement. The contact between the two is concealed beneath a loose cover of boulders everywhere except near the mouth of Fish Creek Canyon. Here it is sharp and conformable. The gray member contains lenses of unconsolidated arkosic sandstone, and sand predominates near the top of the formation. These uppermost sandstone beds contain layers of greenish

clay shale, and in many places near the top a 1- or 2-foot bed of red-brown sandstone is present.

The gray member crops out near the mouth of Fish Creek Canyon and extends eastward to the wash. It also forms the extreme northwest end of the Fish Creek Mountains. To the southeast the red member is absent, and the gray member lies directly on the basement. Here the basal beds are akosic sandstone. In the southeast corner of the wash the Split Mountain formation is represented by as little as 20 feet of arkose, and there is no conglomerate present.

Gypsum. Lying conformably on the gray member of the Split Mountain formation is at least 100 feet of nearly pure, massive gypsum. The basal 10 or 15 feet of the gypsum commonly contains beds of sandstone or shale, but clastic impurities were not found in the main body. Similarly, near the top the gypsum contains interbedded clastic material and grades into the overlying formation. The gypsum deposits are more fully described below.

Imperial Formation. The Imperial formation (Miocene), which overlies the gypsum, consists of marine shale and poorly consolidated orange-colored sandstone. In much of the area the beds have been removed by erosion, but large areas in the southwest part of the wash have been exposed where a covering of recent fans has been partly removed. A second area where the Imperial formation is exposed is at the north edge of the hills between the wash and Fish Creek Canyon.

The contact with the gypsum is gradational. In the northern exposure gypsum containing layers of greenish shale up to half an inch thick is overlain by 5 feet of arkosic sand typical of the Split Mountain formation. The arkose is overlain by about 100 feet of coarse, gray-green arkosic sandstone that is brown when weathered. This sandstone, in contrast to the gray arkose found beneath the gypsum, readily splits into slabs about half an inch thick. Perhaps it, as well as the gypsum, should be included in the Split Mountain formation.

Overlying the fissile sandstone are orange-colored sandstone beds alternating with beds of poorly consolidated, greenish clay shale. The sandstone consists of well sorted, subrounded quartz grains about 0.01 inch in diameter and a minor proportion of tiny biotite flakes. The grains are heavily coated with and cemented by limonite and calcite.

Overlap. The Split Mountain formation, as suggested above, pinches out to the southeast. In Fish Creek Canyon a thickness of 850 feet of the red member alone exists above the wash level. In the prominent cliff near the county boundary, at the foot of which the basement rocks are exposed, over 100 feet of the gray member lies on some 500 feet of the red member, making a total thickness of only 600 feet. The red member does not appear east of the wash. The gray member is as much as 800 feet thick southeast of the United States Gypsum Company's quarry and thins to a mere 20-foot thickness of sand in the extreme southeast corner of the wash. The gray member apparently thins northwestward also; it is only about 500 feet thick at the northwest end of the Fish Creek Mountains.

The evidence of the original distribution of gypsum has been almost entirely removed by erosion. At the north edge of the hills between the wash and Fish Creek Canyon, however, it is but little more than 100 feet

thick; it pinches out entirely between gray sands of the Split Mountain formation within 2000 feet of the county line. Seemingly the low point of the basin shifted during the formation of these terrestrial and saline deposits.

Structure

The principal structural feature in the area mapped is an open syncline bounded by longitudinal faults. The axis of this syncline lies in the wash. Although there is modification by local folding, dips are toward the axis at angles of about 30° or less.

The fault that bounds the synclinal basin on the northeast is along the northeast side of the Fish Creek Mountains near the edge of the area mapped. For most of its length it cuts basement rocks, but at its northwest end basement rocks are in fault contact with the Split Mountain formation and also with a small outcrop of gypsum.

The principal fault in the area is a steeply dipping fault that separates the basement from the sedimentary rocks along much of the southwest side of the wash. In a few exposures the fault appears as a zone of breccia and gouge up to 50 feet in width. The fault zone is exposed near the mouths of the canyons south of the gypsum body on the southwest side of the wash and also high on the fan in the southwest corner of the wash. Two small hills of gypsum at the foot of the steep slope of basement rocks are further indirect evidence of the location of the fault zone.

West of the fault the Split Mountain formation has been folded into a gentle anticline that approximately parallels the syncline in the wash. The northeast limb has been eroded off, leaving the basement rocks exposed.

On the major structural features minor folds have been superimposed. Such a fold exists near the United States Gypsum Company's quarry where a great thickness of gypsum has been folded into a northeast-trending trough. A complementary anticline has brought the gray conglomerate close to the surface on the southeast, and northwest of the trough there is no great quantity of gypsum for about a mile. Similar minor structures probably account for attitudes that depart from the regional trend in the southwestern exposure of the Imperial formation.

Still smaller structures exist in the gypsum that do not involve the underlying formation appreciably. Where the base of the gypsum is exposed in canyons it dips uniformly for distances of as much as 1000 feet. The overlying gypsum is, however, characteristically contorted. Ninety-degree changes in strike and dip within 10 yards are common.

Gypsum Deposits

The existing gypsum deposits are remnants of a formerly thick bed that probably covered a much larger area than that mapped. The largest and thickest remnants are in the northwestern half of the United States Gypsum Company's property. To the southeast erosion has separated the gypsum into detached bodies. The gypsum on the northeast side of the wash dips beneath the aluvium and reappears on the other side. Some small outcrops indicate that the gypsum exists beneath the large body of the Imperial formation that crops out in the southeastern part of the wash. Another large remnant lies above the cliff near the county boundary, and a 100 foot thickness of gypsum occurs on the Roberts and Peeler property. One small remnant indicates that the gypsum once covered the conglomerate that forms the northwest end of the Fish Creek Mountains.

Surface exposures give little evidence of the maximum thickness of the gypsum. Mining operations in the United States Gypsum Company's quarry have disclosed over 100 feet of gypsum above the wash level, and there is no indication of how much deeper it may go. It has already been mentioned that the gypsum in this area has been down folded into a trough and that the base here is unusually irregular. Perhaps, for the area mapped, 100 feet is the average maximum thickness of gypsum remaining above the wash level. In the two small areas where the original thickness has been preserved and is exposed, the gypsum is 100 feet thick or less.

At the base the gypsum grades into the gray member of the Split Mountain formation. Excellent exposures of the base may be seen in the canyons that cut the gypsum on both sides of the wash and it may also be seen in the United States Gypsum Company's workings on both sides of the thick gypsum referred to above. Always gray arkose immediately underlies the gypsum. Toward the southeast there may be 10 feet or more of arkose, but in the northwestern exposures there is likely to be only an inch or two of arkose separating the gypsum from the congromerate. The lowest beds of the gypsum contain interbedded gypsiferous sand or shale. At the base of the gypsum on the southwest side of the wash a 30 foot bed of gypsum lies as much as 50 feet below the main body, but at most places the interbedded sand is only a foot or two thick or at the most, four feet.

The gypsum itself is a compact, equigranular, fine- to medium-grained material with a grayish tinge. Thin, vague, brownish bands are visible in the hand specimen. The microscope shows that the apparently equigranular gypsum has been largely recrystallized into tiny fibers. The gypsum is divided into areas in which the gypsum fibers are aligned or nearly so, and this feature undoubtedly is responsible for the granular appearance of the hand specimens. Here and there may be seen anhedral gypsum grains that are not fibrous. Tiny detrital shreds of biotite exhibiting green pleochroism are uniformly but sparsely distributed. Finely divided opaque matter, perhaps a mixture of iron and manganese oxides, is present and is concentrated to some extent along grain boundaries.

The basal 5 to 10 feet of the gypsum, particularly in the northwestern part of the United States Gypsum Company's property, contains a sooty, black material that chemical tests indicate to be mixed oxides of manganese and iron. White gypsum comprises 60 percent of these beds; the remainder is impregnated with the black matter. Ellipsoidal bodies of white gypsum up to ¾ inch long are mixed with the black, and thin black films occur along the boundaries between the white bodies. Usually there is a crude banding. Close to the surface the black matter has been changed to a brick red color.

Selenite in the form of glass-clear sheets half an inch to 2 inches thick occurs at a few widely separated spots. At these places selenite is interbedded with greenish shale close to the base of the gypsum. Selenite also occurs within the gypsum body.

Gypsum forms smoothly rounded hills covered with brown gypsiferous soil. Beneath the soil lies 5 to 10 feet of leached and porous gypsum. Gullies are deeply incised, narrow, and steep-walled. Gypsum is more resistant to erosion than are the underlying arkose and conglomerate.

Anhydrite. Anhydrite was not found on the surface, but it does occur in the United States Gypsum Company's quarry about 120 feet vertically below the crest of the face. The anhydrite is a fine-grained white rock with a faintly bluish-gray tinge. In thin section anhydrite is seen to be a felted mass of fibrous crystals that have no preferred orientation. The fibers are grouped in knots, and some fibers are arranged in bending and radiating groups. Some knots contains fibers up to 10 times the average size, and here and there may be found blocky cleavage fragments of anhydrite. Like gypsum, anhydrite is clouded with opaque finely divided matter that is concentrated to some extent along grain boundaries.

All the specimens of anhydrite observed have been replaced to some extent by gypsum. Where anhydrite occurs in the quarry, anhydrite-rich beds alternate with beds that are mostly gypsum. The gypsum-rich beds contain subangular masses of anhydrite an inch or two inches in diameter, and these masses are cut by branching threads of gypsum. In the anhydrite-rich beds 1-inch thick layers of gypsum contain lenses of anhydrite $\frac{1}{8}$-inch in size. The microscope shows that no anhydrite is completely free of gypsum and also that even the highest grade of gypsum quarried contains a small amount of anhydrite.

Thin sections of mixed gypsum and anhydrite show that the anhydrite grain size is smallest at anhydrite-gypsum boundaries and increases toward the centers of anhydrite bodies. Gypsum in close proximity to anhydrite does not have the fibrous character already described. Gypsum closely associated with anhydrite is in the form of anhedral grains that do not have a sharp extinction angle. Along boundaries gypsum penetrates far into anhydrite. Within anhydrite bodies gypsum may be hardly more than gypsiferous areas filled with anhydrite fibers. Occasionally gypsum may penetrate anhedral crystals of anhydrite along a rectangular pattern like the anhydrite cleavage.

Away from anhydrite gypsum may be as anhedral grains with a sharper extinction angle than the vague areas described above. Most of them contain corroded anhydrite inclusions. Usually, however, gypsum is fibrous, and the farther from anhydrite the finer are the fibers and the more perfect is their alignment within grains.

Satin spar veinlets up to $\frac{1}{8}$-inch wide cut both gypsum and anhydrite. Usually they are composed of lath-shaped gypsum crystals that are oriented normal to the veinlet walls. These crystals have a sharp extinction. Anhydrite remnants are to be found within these crystals. Veinlets walls, although straight, are irregular in detail. One vein-shaped body of gypsum cutting anhydrite is made up of fibrous gypsum in which there are suggestions of grains arranged like the pattern in the satin spar veinlets.

The evidence suggests that replacement of anhydrite by gypsum began along fractures and proceeded until varying proportions of anhydrite were left as partly rounded remnants. Not enough exposures of anhydrite were found to determine whether a relation exists between depth and the presence of anhydrite. It is probable, however, that calcium sulfate, wherever it is buried to a depth of 100 to 150 feet, exists as anhydrite.

Celestite. Celestite was found only on the Roberts and Peeler property, although specimens of strontium-bearing gypsum in the possession of the United States Gypsum Company are thought to have come from

their property. Celestite forms a dissected cap about 10 feet thick on a hill composed of about 100 feet of gypsum lying on gray conglomerate. There is no indication that celestite occurs at the original top of the gypsum here.

Two small open cuts have been made in the celestite in addition to the natural outcrops. At one place gypsum is interbedded with the celestite, and in another place the celestite immediately overlying the gypsum is in the form of subangular nodules up to 6 inches in diameter. The celestite clearly is conformable with the underlying gypsum and probably is a lens.

The celestite is faintly bluish when fresh, but weathered surfaces are brown and jagged. The rock is composed of a fine- to medium-grained porous mass of anhedral celestite grains with very finely divided calcite grains concentrated along the celestite crystal boundaries. Black oxides are present also. Although most of the celestite crystals are granular, elongate crystals and radiating groups of crystals are to be found.

Quatal Canyon Deposit, Ventura County

A comparative newcomer among California's gypsum producing areas is the northwestern corner of Ventura County. Gypsum occurs about 5 miles east of Ventucopa, a post office and store on U. S. Highway 399 in the upper part of the Cuyama Valley. The deposit consists of a single bed from 10 to 30 feet thick that occurs in mildly folded Tertiary rocks. The outcrop of this bed may be traced for at least 7 miles between Ballinger Canyon and Quatal Canyon.

The principal mining operation is that of the Monolith Portland Cement Company which supplies the gypsum requirements of the portland cement plant at Tehachapi. The Monolith property (109) lies in secs. 18 and 19, T. 9 N., R. 23 W., and sec. 24, T. 9 N., R. 24 W., SBM. in a branch canyon north of Quatal Canyon. It may be reached over a private road half a mile long that leaves the Quatal Canyon road 4.7 miles east of its junction with U. S. Highway 399. Mining of gypsum began here in 1941.

The Blue Diamond Corporation owns patented claims (103) that lie between the Monolith property and Ballinger Canyon. Southeast of the Monolith property and across Quatal Canyon are the claims of W. Mathews (107). The deposit extends still farther southeast into Corral Canyon where the Heffron brothers have a gypsum claim. Development only has been done on these properties.

The only published geologic report of the area known to the writer is that of English [19] with its accompanying map, scale 1:125,000.

English describes some 12,000 feet of coarse sediments of middle and late Miocene age that occur in the area east of the Cuyama Valley and west of the San Andreas fault zone. The sediments are at least in part non-marine. The gypsum occurs at the base of the Quatal red clay, a non-marine facies of the upper Miocene Santa Margarita formation. Underlying the gypsum are the middle Miocene Caliente red beds.[20] The Monolith property lies on the southwest flank of one of a series of open, northwest-trending anticlines that lie east of the Cuyama Valley.

[19] English, W. A., Geology and oil prospects of Cuyama Valley, California: U. S. Geol. Survey, Bull. 621, pp. 191-215, 1916.

[20] Dibblee, T. W., Personal communication.

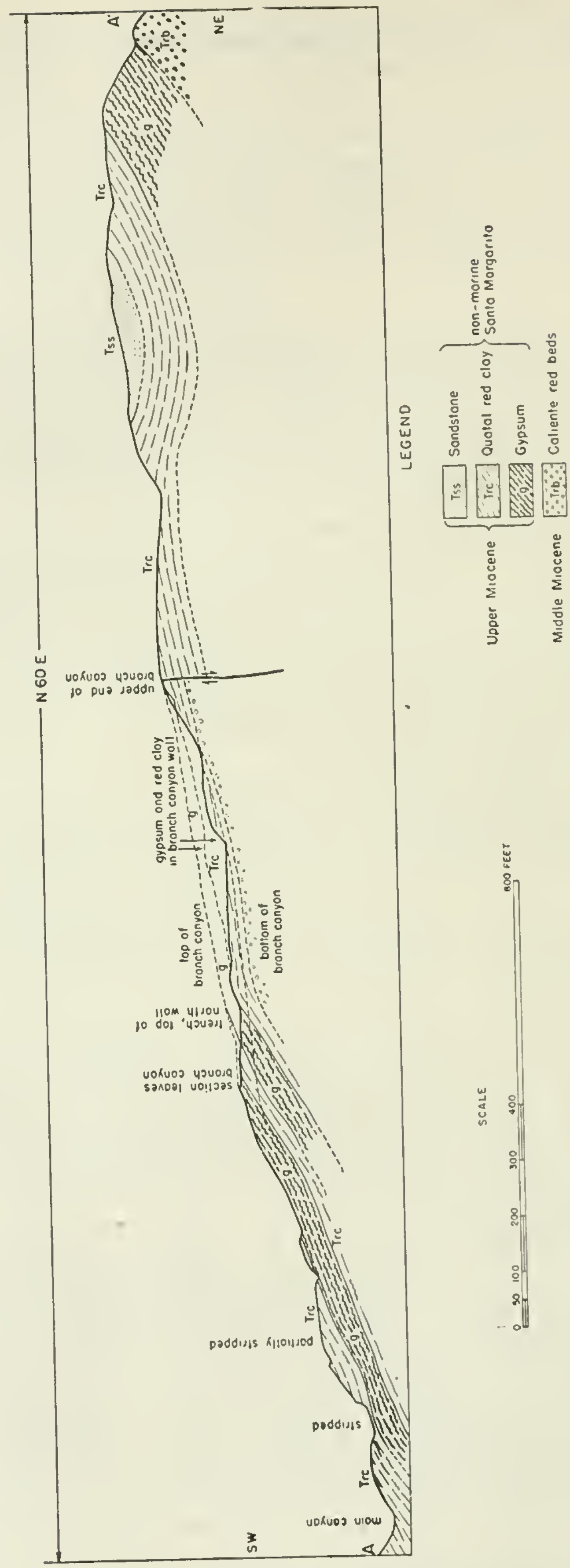


FIGURE 7. Geologic structure section through the Quatal Canyon gypsum deposit.

In the area mapped the gypsum bed is enclosed in 100 to 200 feet of brown shale which in turn is enclosed in many hundred feet of coarse sandstone. The Caliente red beds, which lie in the footwall, are composed of a poorly consolidated sandstone that crops out on the steepest slopes only. The soil overlying it is sandy and in many places contains igneous pebbles and cobbles. One specimen of the sandstone is a poorly sorted material in which the average grain size ranges from $\frac{1}{16}$ to $\frac{3}{16}$ inch, and the maximum size is $\frac{1}{4}$ inch. Grains, which are subangular, are mostly quartz. Feldspar comprises less than 10 percent of the specimen, and a maximum of 5 percent is dark minerals and rock fragments. Most of the quartz grains are blue-gray in color, but some are clear.

The Quatal red clay that encloses the gypsum is a brown claylike shale that does not form natural outcrops, even on the steepest slopes in the area. Soil derived from it is a rich brown loam that supports grass. The shale in places contains selenite crystals and is cut by satin spar veinlets.

Shale was observed in place only in artificial openings. A specimen from the footwall in the Monolith quarry is a light brown material with an irregular fracture. Selenite crystals up to an eighth of an inch in length comprise perhaps 5 percent of the specimen. No other minerals are visible with the hand lens. The footwall shale is about 100 feet thick.

Shale overlying the gypsum in the quarry is much like the footwall shale. The color is lighter, and it has a conchoidal rather than an irregular fracture. The hanging-wall shale here contains no gypsum, but elsewhere soil derived from shale that overlies gypsum contains satin spar fragments. Approximately 50 feet stratigraphically above the gypsum, beds of fine-grained yellow sandstone occur in the shale and crop out in road cuts. The total thickness of shale and fine-grained sandstone above the gypsum is 75 to 100 feet; above that is coarse-grained sandstone similar in all respects to the Caliente red beds.

The gypsum bed ranges from 10 to 30 feet in thickness, and in some places it contains as much as 5 feet of interbedded shale. In artificial openings the gypsum is massive and cut by joints perpendicular to the plane of the bedding. Gypsum crops out more commonly than either the sandstone or the shale, but the outcrops are of porous, weathered material that gives but little indication of the character of the unweathered gypsum below. Soil lying on gypsum is gypsite mixed with organic matter resulting from the decay of coarse grass and bushes that grow on it.

The gypsum itself is a brown-colored, compact aggregate of grains about 0.05 inch in size in which there are indefinite segregations of darker gypsum. Whatever causes the brown color does not, however, affect the purity of the gypsum. Under the microscope the gypsum is seen to be a mosaic of interlocking anhedral grains, many of which are elongate but not oriented. Twinning is uncommon. Grain size ranges from 0.003 x 0.01 inch to 0.02 x 0.10 inch. Each crystal has uniform extinction and well-defined boundaries. Cloudy brown calcite consisting of anhedral grains less than 0.001 inch in diameter occur, commonly along gypsum crystal boundaries. There are also round bodies 0.01 inch in diameter containing mixed gypsum and calcite.

A specimen of impure gypsum from the Blue Diamond area consists of clear gypsum alternating with paper-thin layers clouded with brown, opaque matter. The clear layers are composed of gypsum grains the size

and shape of those described above except that almost all of them have fibrous texture. The cloudy bands contain gypsum and anhedra of dolomite or calcite 0.001 to 0.004 inch in size. Finely divided opaque dust occurs along the grain boundaries.

Within 5 feet of the base of the gypsum, nodules of gray to milky chert are plentiful. Some are reniform; others are lens-shaped. The nodules, which may be up to 4 inches in diameter, are uniformly distributed through the lowest layers of the gypsum and average 5 to 10 feet apart.

A basalt flow, perhaps 20 feet thick, occurs 700 feet stratigraphically below the top of the Caliente red beds in the Blue Diamond area. The comparable stratigraphic position in the Monolith area falls on the face of a steep scarp, and the flow was not located there. The flow is composed of black-colored aphanitic rock, and it has reddened the underlying sand somewhat.

The scarcity of good outcrops in the vicinity of the Monolith deposit and the similarity of footwall and hanging wall rocks makes the interpretation of the structure somewhat difficult. The surface northeast of the branch canyon in which the quarries are is an approximate dip slope that is abruptly cut off on the east by a steep scarp. Over much of the dip slope gypsum crops out and dips uniformly southwestward at angles of from 30° to 45°. Toward the branch canyon the gypsum gradually passes beneath the hanging wall shale and disappears southwest of it under shale and sandstone.

At its upper edge the gypsum is abruptly cut off by an approximately vertical fault the northeast side of which has dropped relative to the southwest side. Northeast dips along the fault suggest that the gypsum has been dragged down along the fault surface. Additional evidence of the fault may be seen on the scarp where gypsum abuts against sandstone.

Some 600 feet northeast of the fault gypsum again appears on the scarp in its normal sequence. The outcrop of the gypsum bed is traceable from here northwestward into the Blue Diamond area. Here also the prevailing dip is southwest, although there are wide but perhaps local departures from the regional trend.

Death Valley Region

China Ranch Deposit (31) (Pl. 34)

A gypsum deposit on China Ranch southeast of Tecopa in sec. 26, T. 20 N., R. 7 E., SBM, was worked in 1916 and 1917 by the Acme Cement and Plaster Company. It is now owned by the Certain-teed Products Corporation of Ardmore, Pennsylvania. The road to China Ranch, which leaves the Tecopa-Noonday road about 3 miles east of Tecopa, passes through the deposit. The deposit was opened with tunnels, and gypsum was produced by open stoping at the rate of 1000 tons a month.

The gypsum occurs in a great thickness of tilted lake beds, probably of Pliocene age, that are composed chiefly of brittle, light brown-colored clay shale. Beds of pumice lapilli up to 15 feet thick occur interbedded with the shale. The principal gypsum deposit is a 20-foot thickness of gypsum beds ranging from 6 inches to 3 feet in thickness separated by up to 3 inches of shale. On both the hanging wall and the footwall the gypsum grades into shale by a rapid decrease in the number and thickness of the gypsum beds. In addition thin beds of impure gypsum occur some distance from the main body and selenite seams a quarter of an inch

thick cut the shale. The gypsum is a compact white to light-gray aggregate of grains 0.025 to 0.05 inch in size. In thin section the texture is seen to be fibrous like that of the Fish Creek Mountains gypsum.

Copper Canyon Deposit (32) (Pl. 34)

An occurrence of gypsum was examined in Copper Canyon about 3 miles above its mouth in the northeastern part of T. 23 N., R. 2 E., SBM. Comparatively thin gypsum beds occur in lake beds that lie on a great thickness of conglomerate extending westward to Death Valley. The lake beds, which contain fossil footprints, have been assigned to the lower Pliocene (?) Furnace Creek formation. They are composed of chocolate brown-covered shale with a minor amount of coarse, pebbly sandstone. Gypsiferous zones, although occurring throughout the lake beds, are most numerous near the base. Most of the gypsum is in the form of thin beds up to half-an-inch thick alternating with shale or gypsiferous shale, but there are a few beds of comparatively pure gypsum up to 5 feet thick.

Furnace Creek Deposit (33) (Pl. 34)

There is an undeveloped gypsum deposit in Furnace creek on the Twenty Mule Team scenic loop, on State Highway 190, 6 miles east of Furnace Creek Inn. Gypsum beds which occur in the lower Pliocene (?) Furnace Creek formation, crop out on the summit of a ridge between the highway and the loop and extend along it for about a mile. A maximum of 3 feet of pure gypsum occurs interbedded with shale; greater thicknesses of gypsiferous shale and thin beds of gypsum alternate with shale. Occurring near the gypsum are lava flows. Gypsum in contact with the lava is chalky, but there is no indication that this effect was produced by the lava.

Owl Hole Spring Deposit (86)

Near Owl Hole Spring in T. 18 N., R. 3E., SBM. is an undeveloped gypsum deposit that has some of the features of Avawatz Mountains deposits. It lies on a branch of the road to Leach Lake which early in 1948 had recently been graded and was marked with a sign. The branch turns west from the Leach Lake Road 11.7 miles from the South Death Valley road, and half a mile further on it passes through a narrow wash where gypsum crops out on both sides. Gypsum and gypsiferous shale occur in Pliocene (?) lake beds that crop out along the wash for about a mile to the east. These beds, which strike parallel to the wash and dip north beneath the wash gravel, are composed of brown shale. The surface of the shale is covered with a thin moldlike efflorescence.

At the spot indicated above, a 2-foot bed of gypsum free of shale impurities crops out for 75 feet and continues across the wash for a short distance. Overlying the gypsum is a bed of salt-impregnated shale. Some of the shale beds in the vicinity contain celestite nodules.

Cuddy Canyon Deposit, Kern County (37)

A gypsum deposit in Cuddy Canyon near Frazier Park has been examined by Gordon B. Oakeshott and James W. Vernon.[21] The gypsum occurs in sec. 34, T. 9 N., R. 21 W., SBM, about 2 miles west of Frazier Park on the south side of the canyon. Although some gypsum has been mined from the outcrop and an inclined shaft has been sunk, no records

[21] Supervising Mining Geologist and Junior Mining Geologist, respectively, California Division of Mines.

are available to indicate when the work was done or the use made of the small amount of gypsum mined.

In this area the most prominent structural and topographic feature is the San Andreas fault zone which trends almost due west following Cuddy Canyon. North of the fault are bodies of crystalline limestone that occur as roof pendants in Jurassic (?) granitic rocks, while south of it is a series of volcanic and sedimentary rocks of Miocene (?) age containing several gypsum-bearing lenses. The gypsum lenses are interbedded with brown sandstone, conglomerate, basalt flows, basaltic agglomerate and tuff striking approximately N. 75° W. and dipping 20° to 85° south. The largest of the gypsum lenses is 15 feet thick and can be traced southeastward from the canyon bed 700 feet up the hillside. The lenses consist of layers of light brown-colored gypsum as much as 3 inches thick separated by the thinner layers of shale.

Mint Canyon Deposit, Los Angeles County (55)

Some development work has been done on a gypsum deposit in Mint Canyon in the western part of sec. 29, T. 5 N., R. 14 W., SBM. A gravel road 6.2 miles north of Solamint turns east from U.S. Highway 6, and 0.3 mile from the highway a side road turns north to the deposit. The deposit has been opened by a 150-yard cut along the gypsum outcrop, but it was idle in November 1948.

A gypsiferous zone up to 15 feet thick that strikes N. 65° E. and dips 40° NW. occurs in tightly folded sedimentary and volcanic rocks of the lower Miocene (?) Vasquez formation. The zone consists of beds up to 6 inches thick of gray and brown-colored gypsum resembling that of the Quatal Canyon deposit alternating with coarse, angular sandstone cemented by gypsum. These rocks lie on a coarse, angular, greenish sandstone containing thin beds of purple-and green-colored shale. Twenty or thirty feet below the gypsum occurs a black, somewhat vesicular lava. Very coarse-grained arkosic sandstone containing a few 3-inch shale beds overlies the gypsum. Granitic rocks are in fault contact with the sediments about 200 yards northwest of the deposit.

Mule Shoe Ranch Deposit, San Benito County (76)

The Mule Shoe Ranch deposit is 0.3 mile west of Bitterwater Road and 1.2 miles south of Bitterwater in secs. 17 and 18, T. 18 S., R. 9E., MDM. (projected). It was last worked during 1945 and 1946 by the Monterey Gypsum Company which produced high grade ground gypsum for agricultural use.[22] In December 1948 the operation was abandoned, and all equipment had been removed.

Nearly flat-lying lenses of gypsum 3 to 6 feet thick and up to 300 yards in diameter occur in beds of the Paso Robles (early Pleistocene) formation. The gypsum is enclosed in silt beds that in turn are enclosed in a moderately hard, poorly sorted, cross-bedded sandstone containing rounded pebbles of weathered siliceous shale up to half an inch in diameter. Two to four feet of silt separate the gypsum from the overlying standstone; and the total overburden including a foot or two of soil ranges from 3 to 10 feet in thickness. The underlying sandstone is exposed in the bottom of a small canyon, a distance of about 25 feet stratigraphically below the gypsum.

[22] Averill, C. V., Mines and mineral resources of San Benito County, California: California Jour. Mines and Geology, vol. 43, p. 51, 1947.

FISH CREEK MOUNTAINS GYPSUM DEPOSIT

Panoramic view south and southeast from the west side of the wash. Gray conglomerate covered with ocotillos appears in the foreground. In the cliff on the right side of the picture a nearly complete stratigraphic section is visible. A basement of granitic and metamorphic rocks exposed at the base of the cliff is overlain successively by red sandstone, gray conglomerate, and gypsum of the Split Mountain (Miocene) formation. The light-colored beds at the head of the wash in the center of the picture are marine sandstone and shale of the Imperial (Miocene) formation overlying the gypsum. Basement rocks form the sky line in the center and left side of the picture. Gypsum bodies east of the wash lie on gray conglomerate on the lower slopes at the left side of the picture.

GYPSUM ON WEST SIDE OF WASH

Fish Creek Mountains deposit. At the northwest side of a canyon that cuts through the gypsum. Gypsum lies on gray arkose and the arkose on gray conglomerate. The gray conglomerate crops out in the little notch on the ridge. In the middle distance is the Roberts and Peeler strontium mine where celestite occurs interbedded with gypsum.

BASE OF GYPSUM

Fish Creek Mountains deposit. The contact is at the hammer head. Gypsum lies on gray arkose of the upper part of the Split Mountain (Miocene) formation.

GRAY CONGLOMERATE

Fish Creek Mountains gypsum deposit. Exposed in a cut at the extreme north end of the range. This material underlies the gypsum.

SANDSTONE-GRANITE CONTACT

Fish Creek Mountains gypsum deposit. Red sandstone of the Split Mountains (Miocene) formation lies with depositional contact on deeply weathered granite. The contact is close to the hammer head.

GYPSUM HILLS

Fish Creek Mountains deposit. View east of the United States Gypsum Company quarry toward the southeast. Gray conglomerate that underlies the gypsum occurs beyond the gypsum and on the sky line. The gray conglomerate lies on basement rocks, which are visible on the sky line at the extreme right.

UNITED STATES GYPSUM COMPANY QUARRY

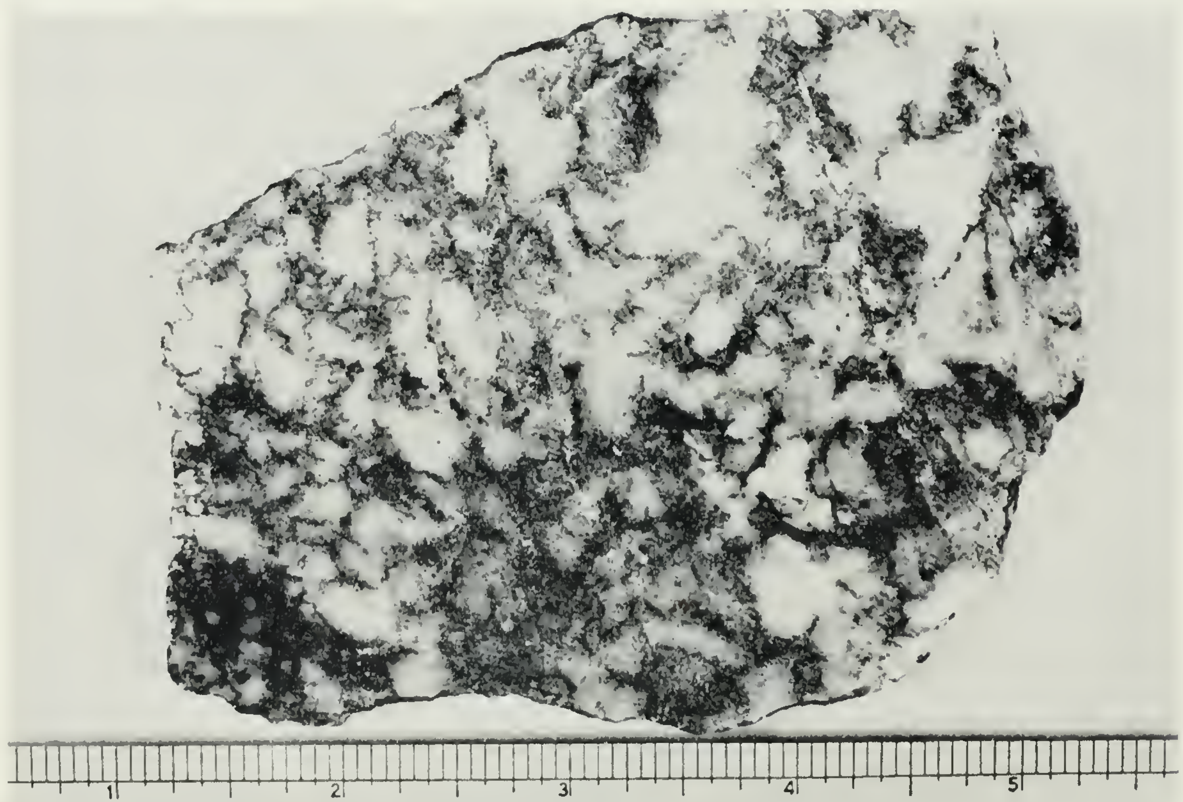
Fish Creek Mountains. Northwest corner of quarry. The underlying gray conglomerate is exposed on the little ridge near the left edge of the picture. The quarry face is well over 100 feet high.

BASE OF GYPSUM

Fish Creek Mountains deposit. Close to the base of the canyon wall arkose rests on gray conglomerate. Gypsum rests on arkose. The thin dark bands are greenish shale. The distance from the floor of the canyon to the top of the picture is about 20 feet.

GYPSUM AND ANHYDRITE

Fish Creek Mountains deposit. Light anhydrite, dark gypsum. A boulder of waste at the United States Gypsum Company quarry. Anhydrite occurs abundantly in the quarry about 120 feet vertically below the crest of the face.

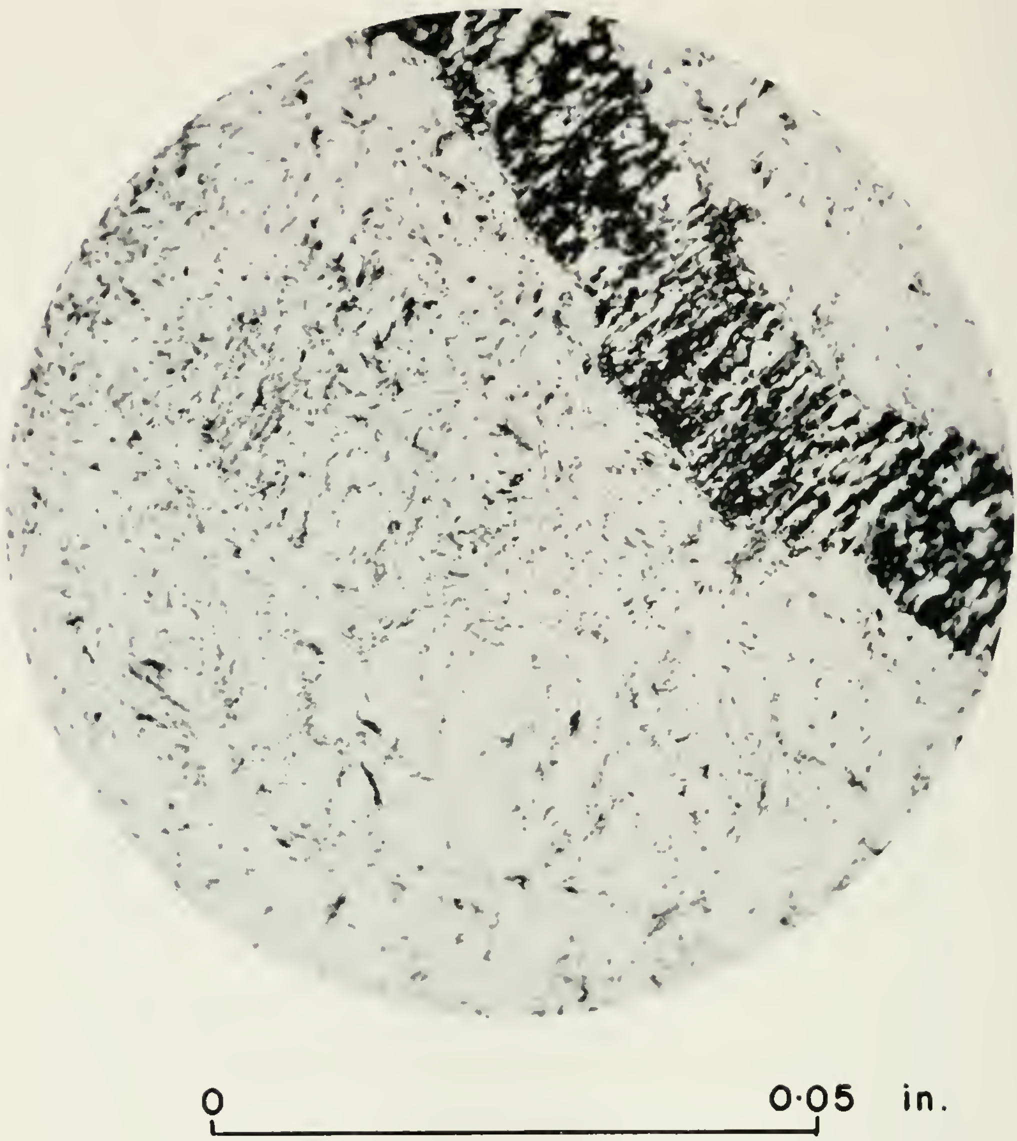


SPECIMEN OF MOTTLED GYPSUM

Specimen of mottled gypsum from United States Gypsum Company's quarry, Fish Creek Mountains. High quality gypsum is stained by black films of finely divided manganese and iron oxides.

SPECIMEN OF ANHYDRITE

Altering to gypsum, United States Gypsum Company's quarry, Fish Creek Mountains. Anhydrite, light; gypsum, dark.



PHOTOMICROGRAPH OF FIBROUS ANHYDRITE
Cut by satin spar veinlet, Fish Creek Mountains. Crossed nicols.

The gypsum itself is a compact, fine-grained, granular rock that is tan in color. In the single specimen studied in thin section the texture resembles that of the Quatal Canyon gypsum except that parts of the slice contain subhedral to euhedral diamond-shaped gypsum crystals.

Cuyama Valley Deposits, Santa Barbara and Ventura Counties

In the upper Cuyama Valley region there is a second gypsiferous zone about 5 miles southwest of the Quatal Canyon deposit. The gypsum occurs in the Caliente (middle Miocene) red beds; in this area the Santa Margarita formation (late Miocene) which contains the gypsum at Quatal Canyon, is non-gypsiferous.[23] Deposits along the zone for a distance of about 7 miles were examined, and the zone probably extends farther in both directions. In contrast to the Quatal Canyon deposit, however, the zone consists largely of numerous thin beds of gypsum separated by gypsiferous sediments.

Although development has been carried out at a number of places, shipments have been small. In the summer of 1950 the Maricopa Gypsum Company had made agreements to do assessment work on a number of gypsum claims with options to lease them. The Cuyama Gypsum Company held a license to produce agricultural gypsum in 1946.

The following is a list of properties where development work has been done and from which a little gypsum may have been shipped. A deposit belonging to L. Curyea in the SE$\frac{1}{4}$ sec. 34, and SW$\frac{1}{4}$ sec. 35, T. 9 N., R. 25 W., SBM is on an eastern branch of Santa Barbara Canyon and 6.3 miles up the canyon from U.S. Highway 399 (100). The next property to the east belongs to Harry Black, Merl Black, and Gene Stutz. It is in sec. 36, T. 9 N., R. 25 W. and sec. 1, T. 8 N., R. 24 W. SBM, in Wagon Road Canyon 1.3 miles from its mouth (102). Between here and Cuyama Wash is the Seeley property (101) in the SW$\frac{1}{4}$ sec. 7 and NW$\frac{1}{4}$ sec. 18, T. 8 N., R. 24 W. The River claim of Black et al (105) covers the gypsiferous zone where it crosses the Cuyama River. Development work has been done in the northwest corner of sec. 17 and the northeast corner of sec. 18, T. 8 N., R. 24 W. on the west bank of the river, and some gypsum has been shipped from Frenchman's Point on the east bank in NE$\frac{1}{4}$ sec. 16 and NW$\frac{1}{4}$ sec. 17, T. 8 N., R. 24 W. The easternmost property visited, which is also part of the Black property, is a mile or so farther east on the south side of Burges Canyon in NW$\frac{1}{4}$ sec. 15, T. 8 N., R. 24 W (104). At all of these places the geologic occurrence of the gypsum is similar.

Those of the above deposits that are west of the Cuyama River are in the area covered by English's map.[24] The gypsiferous zone occurs in the middle Miocene Caliente red beds which English designated the Pato member of the Vaqueros formation. These brightly colored red and green nonmarine sandstones are especially noticeable in the beds overlying the gypsum. They form a 2-mile strip bounded by faults that strike about N. 60° W. through the entire area under consideration. Dips are predominantly southwest at angles of 25° to 50°, but the fault block is itself faulted, and there are northeast dips also.

Although the gypsiferous zone may be traced throughout the entire area, it thickens at the places where development has been done to a

[23] Dibblee, T. W., personal communication.
[24] English, W. A., Geology and oil prospects of Cuyama Valley, California: U. S. Geol. Survey Bull. 621, pp. 191-215, 1916.

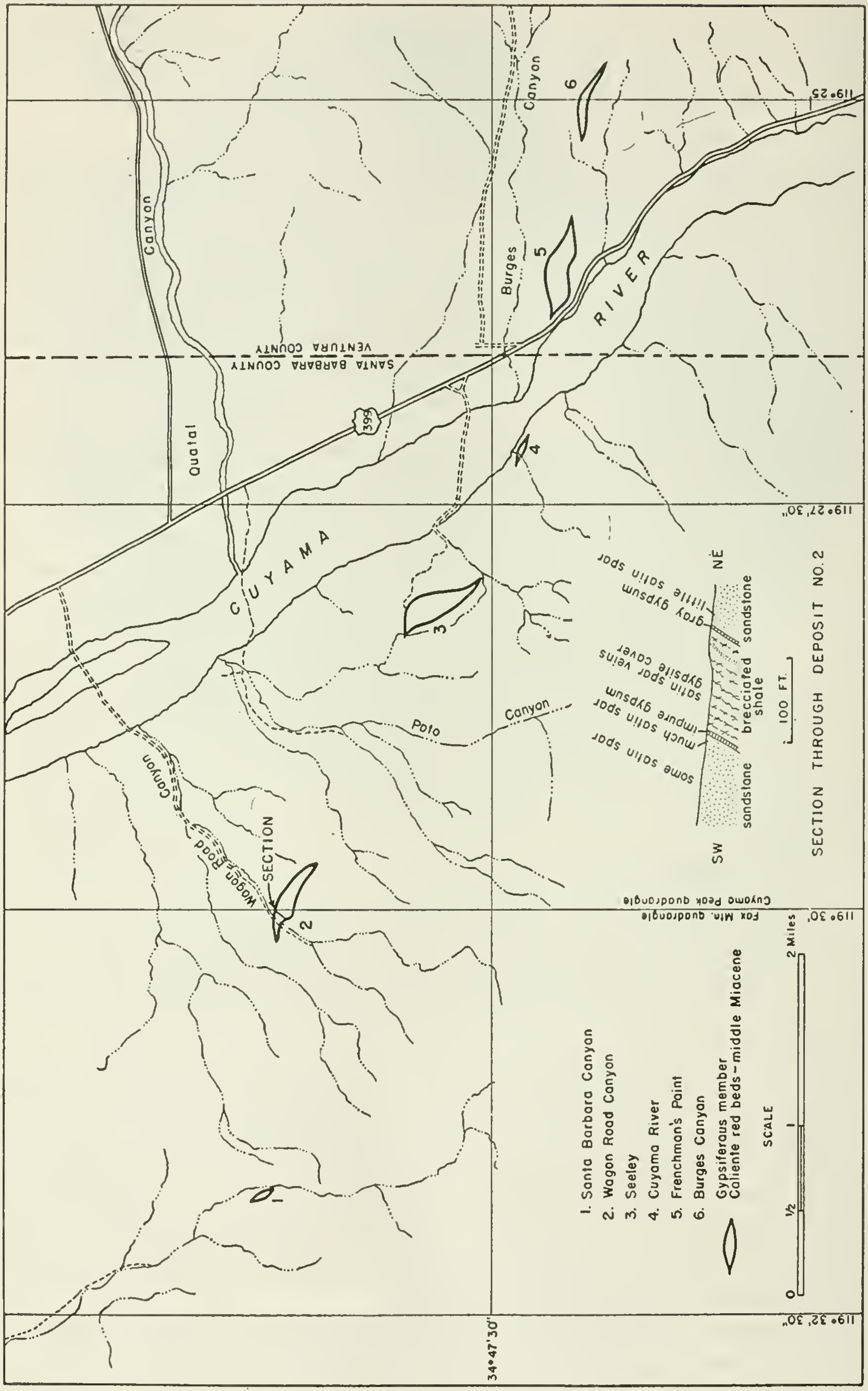


FIGURE 8. Index map showing the location of some gypsum deposits in the Cuyama Valley and geologic section through the Wagon Road Canyon gypsum deposit.

maximum of 50 feet. These wider parts are composed of dark-brown shale, fine-grained poorly consolidated quartzose sandstone, and comparatively thin beds of gypsum containing impurities of greenish-colored shale. These rocks are thoroughly brecciated in many places, and they are commonly crowded with satin spar veinlets up to an inch thick. The highly gypsiferous portions of the outcrop are covered by blankets of gypsite up to 5 feet thick. The section through the Wagon Road Canyon deposit illustrates these features (fig. 8).

Development work has revealed beds of comparatively high grade gypsum up to 10 feet thick. They are, however, extremely lenticular; and commonly they disappear entirely within 100 feet along the strike. Even smaller lenses of high quality alabaster are to be found. The alabaster is used near Ventucopa for carving. Lenticular bodies of alabaster ranging in diameter from a few inches up to perhaps 10 feet occur both within impure gypsum and in brecciated, gypsiferous shale.

A specimen of alabaster from Frenchman's Point was examined under the microscope and found to consist almost entirely of gypsum in a mosaic of slightly elongated interlocking crystals that average 0.005 inch in length. There are a few large irregular anhedra of gypsum up to 0.02 inch in diameter that contain small gypsum crystals at a different orientation from that of the surrounding material.

Avawatz Mountains Deposits, San Bernardino County (79)

Gypsum, together with salt and celestite, occurs in a belt of strongly folded and faulted Tertiary beds that are exposed in the northern foothills of the Avawatz Mountains. These beds crop out in a belt about 9 miles long and a mile wide that extends from sec. 8, T. 17 N., R. 6E., near Sheep Creek northwestward to sec. 24, T. 18 N., R. 4 E., SBM. The deposits are included in claims of the Avawatz Salt and Gypsum Company that were patented about 1911. There has been no production, and no work has been done on the gypsum deposits in recent years. Exploration of portions of the salt deposit carried out in 1941 and 1942 had no direct bearing on the gypsum. The Western Atlas Corporation held a lease on the property and developed talc bodies associated with the basement rocks. The property is remote from paved highways, although some of the old access roads have been regraded. Although the road from Barstow through Camp Irwin is passable, the best approach is from the South Death Valley road.

The only detailed and comprehensive geologic report on the Avawatz saline deposits is the unpublished report of Lewis and Johnson.[25] A report written by H. C. Lee and L. F. Boyer, in 1942, also unpublished, is confined to a small portion of the salt deposit where gypsum does not occur. Gale [26] has summarized and evaluated the earlier work after reviewing the area in the field with L. F. Noble. Gale's report, primarily on the salt resources, contains a geologic map of the central third of the Avawatz Salt and Gypsum Company property.

Structurally the region is so complex that no uniformity of opinion exists among those who have studied it in detail. The salines occur in lake beds of late Miocene or early Pliocene age and were formed by evaporation of the water of a closed basin or basins. The Tertiary beds are

[25] Lewis, J. O., and Johnson, H. R., Unpublished report prepared for the Avawatz Salt and Gypsum Company, July 31, 1911.
[26] Gale, H. S., Avawatz salt, gypsum, celesite and talc deposits, San Bernardino County, California, 37 pp., unpublished manuscript, December 1947.

involved in the South Death Valley fault system, a series of faults that may be traced for at least 30 miles northwestward along the south side of Death Valley. The merging of this fault system with the Garlock fault near Sheep Creek in the eastern end of the property is the apparent reason for the structural complexity of the area.

In the opinion of those who have worked in the area recently, the granitic and metamorphic rocks that form the main mass of the Avawatz Mountains have been thrust northeastward over the Tertiary rocks.[27]

The following interpretation of the stratigraphy is by Lewis and Johnson with slight modifications by Gale. One prominent formation is a breccia, probably of Tertiary age, composed of rocks similar to those of the core of the Avawatz Mountains where gneiss, marble, and quartzite have been intruded by granite and gabbro. In the area under consideration the breccia occurs in two steeply dipping slices, one facing Death Valley and one farther south, separating two belts of complexly folded and faulted gypsum and salt-bearing Tertiary lake beds. The two belts of Tertiary rocks are close together at the east end of the property and diverge westward at a slight angle.

The gypsum- and salt-bearing beds are divisible into four parts. The older Tertiary beds, which contain neither salt nor gypsum, are made up of a lower section of maroon-colored or deep red-colored shale and an upper section of fine-grained argillaceous yellow-colored sand. Their thickness is 267 feet at Cave Spring Wash.

The older Tertiary beds grade upward into the gypsum-bearing beds, which range from 150 to 400 feet in thickness. The base is marked by the first appearance of gypsum in quantity and the top by the last appearance of gypsum. Gypsum occurs as relatively thin beds of fine-grained rock gypsum alternating with greenish gypsiferous clay and forms from a small fraction up to two-thirds of the total thickness. Some of the gypsum is heavily stained with manganese oxides, but in general it is free from salt. Particularly in the western part of the property, celestite is found near the base of the gypsum-bearing beds. The celestite occurs as reef-forming beds of hard, dark-weathering rock up to 3 feet thick that may be traced for as much as 1,000 feet. Along the strike, they thin out and are represented by nodules of celestite in gypsum.

The salt-bearing beds overlie the gypsum and consist of yellowish and reddish salty clay and sand that contain rock salt in the central part. The thickness is difficult to determine because of the lack of structures in the salt. Although the salt is in general concealed by a layer of residual impurities, exploration in the Boston-Valley salt claims has disclosed 275 feet of massive salt, averaging more than 92.0 percent NaCl. The salt-bearing beds grade upward into the post-salt beds, 800 feet of gravel and sand containing a minor proportion of gypsiferous and saline beds.

Overlying the post-salt beds with marked angular unconformity are beds of boulder conglomerate that are horizontal or broadly folded. Noble has correlated them with the Funeral fanglomerate of probable late Pleistocene age. Still younger, but older than the Recent terrace gravels and alluvium, is the older alluvium, remnants of alluvial fans that have been dissected by later stream channels.

[27] Hewitt, F. L., Personal communication.

The detailed structure of the two gypsum- and salt-bearing belts has not been solved. In part, at least, this is because of the lack of detailed study, for only in one limited area has a complete program of exploration been carried out. In part, the massive character of the salt obscures structures in it. Interpretations of the structure by different geologists are widely divergent. The relative ages of the sediments have not been definitely determined, and it has even been questioned that the normal order of precipitation of gypsum followed by salt took place here.

The following five areas are illustrative of the general nature of the gypsum deposits (pl. 36).

The West End. Some low hills at the west end of the Avawatz Salt and Gypsum Company property and in the broad fan slopes northwest of Denning Spring are known as the West End. The old road from Denning Spring to Confidence Mill lies about half a mile east of these hills, and early in 1948, it was possible to drive north on it to a point east of the hills. Because of the relatively low relief and small amount of overburden, the West End has been considered to be the most favorable place to mine gypsum.

In these hills the gypsum-bearing beds are involved in two or more domal anticlines revealed under the terrace and wash gravels, and are covered with little, if any overburden. Although they dip steeply southwest, the beds are less contorted here than elsewhere on the property. The accompanying section shows a maximum thickness of 150 feet consisting of gypsum beds up to a foot thick separated by thin layers of clay. This relatively pure gypsum grades both upward and downward into interbedded gypsum, clay, and sand, with a decreasing proportion of gypsum. Certain beds are heavily stained with manganese and iron oxides.

Celestite is more abundant in the West End than elsewhere in the property. It occurs both as solid beds and as layers of nodules within the gypsum.

Big Gypsum (Kelley) Hill. Big Gypsum (Kelley) Hill, a conspicuous outcrop of gypsum on the northwest side of Denning Spring Wash, is the northwest extension of the same belt of lake beds that occurs in Salt Basin. A rough but passable road that turns south from the South Death Valley road and follows the wash, passes close to the southwest end of the hill. The gypsum is 1.5 miles from the South Death Valley road.

The structure has not been determined definitely. Although as seen from a distance the gypsum-bearing beds apparently lie on the brecciated basement rocks with normal depositional contact, a complicated system of faults has been postulated to explain the relations observed. Depending on the interpretation of the structure, Big Gypsum Hill may or may not contain a large tonnage of gypsum.

Salt Basin. Salt Basin, a valley trough formed by the dissolving of salt, is flanked on the north by a considerable thickness of the gypsum-bearing beds. The gypsum has received more study in this area than in any other part of the property. Salt Basin is best reached from the unimproved road in Denning Springs Wash, from which, 1.3 miles south of the South Death Valley Road, a branch turns southeastward and crosses Cave Spring Wash to the deposit.

The accompanying section extends between the two ridges of brecciated basement rocks and crosses the northern belt of gypsum- and salt-bearing lake beds. The structurally weak gypsum-bearing beds, which have been intricately contorted and tightly folded, are exposed in gulches that flow northeast into Salt Basin. In addition, a prospect tunnel has cut 200 to 300 feet of the beds.

On the south, breccia is in fault contact with relatively undisturbed mudstone. This slightly consolidated, but well-bedded material is gray to red in color and contains conglomerate lenses and a minor proportion of thin gypsiferous layers. Possibly in fault contact with the non-gypsiferous beds are interbedded gypsum and gypsiferous clay beds that are intensely crumpled and stand nearly vertically. Although some gypsum beds are up to 10 feet thick, the dump at the prospect tunnel suggests that the section as a whole contains a large proportion of clay.

Northward the gypsum-bearing beds grade into gray to reddish mudstone that becomes salty. Salt is believed to lie beneath the floor of Salt Basin, and around the sides salt forms outcrops covered with red-brown clay that is in marked contrast with the tan outcrops of the gypsum-bearing beds. North of Salt Basin the salt is followed by steeply dipping salty mudstone that is in fault contact with brecciated basement rocks.

Jumbo Deposit. The Jumbo deposit is in the north belt of lake beds, about 2 miles southeast of Salt Basin. It may be reached from the South Death Valley road on an unimproved track that begins 5.6 miles from the State Highway 127 and follows an unnamed wash. Salt and gypsum occur on the east branch of this wash 4.0 miles from the South Death Valley road.

The lake beds, as shown in the accompanying section, are in fault contact on the south with brecciated marble and granite. Northward lie several hundred feet of crumpled gypsiferous mudstone and sandstone and then 20 to 30 feet of gypsum comparatively free from clay. In fault contact with the gypsum beds is a massive body of salt, the outcrop of which is 150 feet wide. North of the salt and in fault contact with it are gypsum and clay beds that become less gypsiferous northward before disappearing beneath terrace and wash gravels.

Sheep Creek Deposit. The Sheep Creek gypsum deposit is at the eastern end of the Avawatz Salt and Gypsum Company property and close to the intersection of the Garlock and South Death Valley fault systems. The Sheep Creek talc deposit, which is associated with the basement rocks, lies about half a mile to the north. A road, marked by a sign in 1948, goes from the South Death Valley road for about 5 miles to a cabin near Sheep Creek Spring. The gypsum lies about a quarter of a mile farther up the first canyon that bears to the west.

The gypsum-bearing beds occur in a belt about 200 yards wide that is bounded by steeply dipping faults. Brecciated granitic and metamorphic rocks lie both to the north and to the south, and about half a mile to the east the belt of lake beds pinches out. The lake beds are severely contorted and are either vertical or dip steeply northwest. Gypsum occurs in them as beds up to 6 inches thick that are separated by thin layers of powdery greenish clay.

QUATERNARY LAKE (PLAYA) DEPOSITS

Some of the playa lakes found in desert regions contain enough gypsum to be commercial sources. Playas are those undrained desert basins that are almost entirely filled with mud. Although they may be covered with a few inches of water after heavy rains, normally the water level is some distance below the surface; and they present an expanse of dried mud covered with an efflorescence of evaporated salts. A small proportion of the playas contain crystal bodies of mixed salts that form a porous mass filled with the mother liquor from which the salts crystallized. The crystal body occupies but a small part of the playa. The gypsum in playas is usually in the form of a mesh of selenite crystals from a quarter of an inch up to an inch long or more.

Bristol Lake, San Bernardino County

The most important source of playa gypsum in California is Bristol Lake, San Bernardino County, near Amboy. From 1906 to 1924 gypsum obtained from the lake about 2 miles southeast of Amboy in secs. 3 and 10, T. 5 N., R. 12 E., SBM. (81), supplied the largest plaster mills in California at the time. The first mill, built by the Pacific Cement Plaster Company, was at Amboy; but about 1916 a new mill was built on the lake close to the deposit. This property now belongs to the United States Gypsum Company, which also owns land in secs. 19 and 30, T. 5 N., R. 12 E., SBM. south of Amboy and on the west side of the lake. In 1935 the Bolo Gypsum Company held property on the east side of the lake (80) but there is no record of production.

Bristol Lake, which lies in a trough, is filled with brine-saturated, fine sediments covered by a hard, salt-crusted surface. In the central part of the lake extensive beds composed primarily of common salt lie within 4 to 8 feet of the surface, while the underlying mud is saturated with concentrated brine containing sodium chloride and calcium chloride. One or more deeper salt beds are believed to exist but have not been explored. Selenite crystals and celestite nodules are found in the mud near the lake margin.

Gypsum has been found at or close to the surface and within a mile of the shore all around the lake, but it is most abundant on the west and north sides. Salt beds do not occur in these marginal areas. Although the character of the gypsum varies, in most places a mush of selenite crystals mixed with salty mud lies beneath a few inches of silt covered with a salty crust. Crystals on the west side of the lake are $\frac{1}{16}$- to $\frac{1}{4}$-inch in size and comprise perhaps two-thirds of the mass, while those near the site of the calcining plant are flat plates up to an inch long, half an inch wide, and one-eighth-inch thick. Hess [28] states that in the areas being worked in 1909, gypsum extended from within a foot of the surface to an unknown distance below the level of the water, which rose to within 8 feet of the surface. Of the excavations on the west side of the lake, which were examined in 1948, few are deeper than 4 feet; and in many of them the gypsum content is greatest about 3 feet below the surface.

In the 1906-1924 operation, the gypsum from Bristol Lake required special treatment to remove the salt and silt before it was processed further.

[28] Hess, F. L., California, in Stone, R. W., and others, Gypsum deposits of the United States: U. S. Geol. Survey, Bull. 697, p. 82, 1920.

Danby Lake (85), San Bernardino County

Danby Lake, San Bernardino County, contains deposits of selenite that resemble those of Bristol Lake, but there has been no production.[29] Danby Lake lies roughly 35 miles southeast of Bristol Lake, and the two occupy the same structural trough. The Parker branch of the Santa Fe Railroad runs along the northeast shore of the lake. By road Danby Lake is best approached from the southeast. The road from Freda Station on the Desert Center-Vidal highway to Saltmarsh station on Danby Lake was passable in 1951.

Danby Lake, like Bristol Lake, contains a bed of salt ranging from 2 to 10 feet thick and covered by from 3 to 15 feet of overburden; but the brine, with which it is saturated, contains no appreciable quantity of calcium chloride. The salt lies in the central part of the lake, including the area from sec. 21, T. 2 N., R. 17 E., SBM. to sec. 23, T. 1 N., R. 18 E., SBM. Northeast of the central area that contains the salt, the marginal silt contains abundant clusters of selenite crystals an inch or more in size. They were observed about 2 miles S. 21° E. of Saltmarsh station, where selenite crystals comprise up to a third of the lake beds exposed at the surface. It is possible that the selenite may extend along much of the northeast shore of the lake, but this has not been ascertained.

Where selenite is abundant, numerous knobs as much as 15 yards in diameter project 5 or 10 feet above the lake surface. They are composed of silt mixed with gypsum crystals approximately 0.01 inch in size and possess a crude layering that is nearly vertical, mushrooming upward and outward. Probably the knobs were formed by the evaporation of upward-moving water that contained calcium sulfate.

RECENT DEPOSITS (GYPSITE)

Gypsite is an unconsolidated earthy mixture of very finely divided gypsum and clay or silt. Calcium carbonate is usually present. Samples may contain 80 percent or more gypsum, but because of the irregularity of the deposits little of the gypsite on the market is guaranteed to contain more than 70 percent gypsum. Much of the gypsite used for agricultural purposes contains from 50 to 60 percent gypsum, and some material with a gypsum content of only 30 percent has been sold. The deposits usually are at or within a few inches of the surface. Deposits as thin as 6 inches have been worked, and few exceed 6 feet in thickness.

Gypsite forms only in regions of little rain and high evaporation. Capillary action draws calcium sulfate-bearing ground water toward the surface where very small crystals of gypsum form. Gypsite deposits are especially numerous and best known in the southwestern part of the San Joaquin Valley. Here their proximity to the San Joaquin Valley farms has made their mining profitable. Gypsite occurs also at many places outside the San Joaquin Valley, and some of the deposits are being worked or have been in the past. Deposits at Koehn Lake, Kern County, and a number of places in the southern Coast Ranges are being worked today. Gypsite has also been mined at Palmdale, Los Angeles County; Corona, Riverside County; and in Carrizo Plain, San Luis Obispo County. Gypsite is commonly associated with the large

[29] Noble, L. F., Nitrate deposits in southeastern California with notes on deposits in southeastern Arizona and southwestern New Mexico: U. S. Geol. Survey Bull. 820, pp. 57, 58, 1931.

deposits of rock gypsum that occur in the desert but are too remote to be of economic interest.

Three types of gypsite deposit have been recognized; those that form caps on the upturned edges of gypsiferous beds, those that occur along the margins of certain periodic lakes, and those that have formed in the beds of dry washes. Deposits that have formed on the upturned edges of gypsiferous beds are probably the most numerous. The gypsum in the source beds may be in the form of selenite crystals and cleavage plates, as part of the cement of sandstones, as a network of satin spar veins, or as thin layers of gypsum interbedded with shale. The overlying gypsite bodies closely parallel the present surface except that the thin overburden of soil is likely to be thinner high on hillsides than it is toward the base. Usually the gypsite becomes less pure downward and grades into the underlying gypsiferous source material. On slopes some migration of gypsite takes place because locally gypsite may lie on non-gypsiferous rock. Individual bodies vary in size from patches up to deposits covering several acres. The average maximum thickness is 3 or 4 feet, but thicknesses of as much as 8 feet occur in a limited area. The gypsite is tan to cream in color and is usually soft. It is composed of unconsolidated crystals of gypsum 0.002 inch or less in length, mixed with quartz grains.

Relatively large gypsite bodies occur along the margins of periodic lakes. Efflorescent deposits have formed along the shore line from calcium sulfate dissolved in the damp underlying soil even though the lake water itself may never have been saturated with gypsum.[30] Gypsite bodies so formed are flat irregular lenses that lie with a sharp contact on lake beds. Sometimes the gypsite crops out, but usually it is covered with up to 3 feet of sandy soil. Solution cavities and interbedded layers and lenses of gravel or unconsolidated sand are a characteristic feature. Specimens of gypsite from these deposits resembles that which forms on outcrops except that the gypsum crystals of the lake margin type are about 0.004 inch long or a little larger.

The third type is represented by gypsite deposits near McKittrick that have formed in the beds of dry washes. They are long, narrow, crooked bodies covered by up to 5 feet of slightly consolidated sand and gravel. Gypsite occurs on the surrounding hills, and the gypsite in the channels may have been washed in from the hills. The channel gypsite may also have originated from gypsiferous ground water that accumulated in the channels.

Fresno County Deposits

Little Panoche Valley Deposit[31] (9)

The Little Panoche Placer deposit is operated by A. D. Sousa of the Agricultural Minerals and Fertilizer Company, Los Banos, and was opened by him in 1946. The deposit is located in SE¼ NW¼ and NE¼ SW¼ sec. 1, T. 14 S., R. 10 E. MDM. In 1949 it could be reached over an unimproved road 1.5 miles long that leaves the Little Panoche Valley road 5 miles south of Mercy Hot Springs.

The deposit consists of a comparatively small patch of gypsite perhaps 500 feet in diameter and averaging 2 to 3 feet thick that lies on a north-

[30] Hess, F. L., California, in Stone, R. W. and others, Gypsum deposits of the United States: U. S. Geol. Survey Bull. 697, pp. 71-73, 1920.

[31] See also Merced County.

west-trending spur of the Panoche Hills. Bedrock in the vinicity of the deposit is largely covered by soil, and the base of the gypsite has not yet been exposed. A steeply dipping bed of coarsely crystalline limestone crops out discontinuously along one edge of the deposit and may be traced several hundred yards. Elsewhere within the gypsite are outcrops of greenish, arkosic sandstone.

Gypsite from this deposit is guaranteed to contain 70 percent gypsum. Mining is done with a scraper operated by a double drum hoist.

Panoche Hills Deposits

The Panoche hills deposits are on the east flank of the Panoche hills at an elevation of about 100 feet above the floor of the San Joaquin Valley. They are 20 to 25 miles south of Dos Palos. Gypsite was first mined here by Paul Schuck prior to 1913. The Dos Palos Gypsum Company (Divens and Conrowe) was active from 1933 to 1941, while Green and Collins worked a deposit adjoining the Dos Palos Gypsum Company operation on the south from 1934 to 1939. In 1947 the Super Gypsum Company began working approximately the same ground as Green and Collins, and in 1948 R. P. Jones reopened the deposit adjoining on the north that had been worked earlier by Divens and Conrowe.

The Valley View mine (17) of R. P. Jones is in sec. 19, T. 14 S., R. 12 E., MDM. An unimproved road marked in 1949 by a sign leaves the Dos Palos Road 19.3 miles south of the railroad crossing at South Dos Palos. The deposit is 3.7 miles from the road junction.

The bed rock here, a member of the Domengine (Eocene) formation, is a soft sandstone, containing *Turritellas*, that has more indurated beds about 20 feet apart. The weathered rock is purplish-red in color, and much of it is cut by closely spaced satin spar veinlets. At least in places the unweathered rock contains little or no gypsum. The beds dip at about 30° toward the valley and strike at a slight angle to the northeast-trending spurs that project toward the valley from the main mass of the Panoche Hills. Gypsite occurs on the tops of these ridges and extends down the flanks. It extends farther down the northwest flanks than the southeast flanks, perhaps because the surface is more nearly normal to the dip of the beds on the northwest flanks. In the intervening gullies gypsite is either lacking or thin and deeply buried. A cut in a gully bottom 10 to 15 deep that was excavated for a loading chute penetrated no gypsite. At another place a few inches of gypsite were found beneath 20 feet of alluvium.

Individual gypsite bodies are small and irregular and are covered in most places by a foot of soil. The gypsite grades downward into the underlying bedrock. In places sand derived from the sandstone lies beneath the gypsite. Many of the bodies are full of residual stones and a shaking screen with $\frac{3}{4}$-inch openings has been installed to remove as much as possible of the non-gypsiferous material. Gypsite sold from the Valley View mine is guaranteed to contain 50 percent gypsum.

Tumey Gulch Deposits

The gypsite deposits of Tumey Gulch occur on northeast-trending spurs of a ridge that lies between the San Joaquin Valley and the mouth of the gulch. The Paoli Gypsum Company produced some gypsite here before 1900 from the northeast corner of sec. 1, T. 16 S., R. 12 E., MDM, and a study of the deposit was made by Professor E. W. Hilgard of the

University of California soon after gypsite was discovered there.[32] A. P. Shepard's Paoli mine produced a substantial tonnage from 1930 to 1939, thus being among the first to enjoy the modern boom in agricultural gypsum. The Paoli mine was in secs. 1 and 2, T. 16 S., R. 12 E., MDM, partly on Shepard's own land and partly on land belonging to H. H. Welsh. Gypsite was recently produced by two enterprises, J. K. Griffin, trustee of the H. H. Welsh estate, and the Bahr mine.

The Bahr mine (6) is on land leased from the Welsh estate in sec. 1, T. 16 S., R. 12 E., MDM, and it adjoins the Griffin deposit on the east. Gypsite had been produced here in 1947, but the deposit was idle in December 1948. Gypsite occurs on the flanks of spurs trending toward the San Joaquin Valley and at a considerable distance from the main ridge bordering Tumey Gulch. Maximum thickness is 3 feet, and much of it contains impurities of sand and gravel.

The Tumey Gulch deposit (16) of J. K. Griffin is in sec. 1, T. 16 S., R. 12 E., MDM, at the mouth of Tumey Gulch. It is west of the Bahr mine and at a higher elevation. Bedrock is a poorly consolidated sandstone of the Vaqueros (Miocene) formation that lies on a more indurated sandstone containing brown fossiliferous beds. The bedrock is covered in most places with 2 to 3 feet of gravel composed of sandstone and a minor amount of quartz and chert. Small scattered gypsite bodies occur almost invariably on the slopes of the spurs that trend northward from the ridge bordering Tumey Gulch. The average maximum thickness of gypsite is 4 feet, but thicknesses of 8 feet are known over a limited area. Although there are a few outcrops, gypsite is in most places covered with sandy soil that is in sharp contact with the gypsite. At the base the gypsite grades into sand and gravel that commonly contains crystals and cleavage fragments of selenite $\frac{1}{4}$ to $\frac{1}{2}$ inch in size. A carryall scraper was used for both stripping and mining the gypsite. A screen and hammer mill have been installed to produce a ground product. The deposit has not been worked since 1949.

Griffin also mined gypsite from sec. 6, T. 16 S., R. 13 E., MDM, and gypsite extends southeastward into sec. 3, 4, and 5 along Monocline Ridge. In the Tumey Gulch area the mineral rights of parts of the Welsh property now belong to S. C. Lillis. These include parts of sec. 36, T. 15 S., R. 12 E. and sec. 2, T. 16 S., R. 12 E., MDM.

Kern County Deposits

Kern Lake Deposits

Gypsite on the south margin of Kern Lake, which has been drained, was described by Hess[33] in 1910. Hess' theory of the origin of the gypsite found on the margins of some periodic lakes was based in part on a study of these deposits. No production was made, however, until the Pacific Gypsum Company in 1946 and the Crystal Gypsum Company in 1947 commenced operations.

The Crystal Gypsum Company's deposits (36) are in secs. 27, 34, and 35, T. 32 S., R. 27 E., near the south margin of Kern Lake. The property, which adjoins the Pacific Gypsum Comnany's holdings on the south and west, may be reached from the Old Maricopa Road at a point 5.2 miles west of U. S. Highway 99 where a road 1.1 miles long leads to the deposit.

[32] Mines and mining products of California: California State Min. Bur. Rept. 12, pp. 323, 324, 1894.
[33] Hess, F. L., California, in Stone, R. W., and others, Gypsum deposits of the United States: U. S. Geol. Survey Bull. 697, pp. 71-73, 1920.

Numerous shallow pits and test cuts have exposed lake beds and small unmined remnants of gypsite. The pits range in size from 10 yards in diameter and 1 foot in depth to 100 yards in diameter and 3 feet in depth. Apparently the gypsite was in the form of comparatively small, scattered lenses. In December 1948 many of the pits were flooded, and the property was idle.

The Pacific Gypsum Company is operating a gypsite deposit (46) in sec. 26, T. 32 S., R. 27 E. on the south margin of Kern Lake and east of the Crystal Gypsum Company's property. The deposit may be reached over a 1.3 mile access road that leaves the Old Maricopa Road 4.5 miles west of U. S. Highway 99. In December 1948 the route was well marked with signs. Numerous lenticular bodies of gypsite 1 to 3 feet thick lie within 3 feet of the surface. The upper part of the gypsite is clean and soft; downward it becomes harder and contains streaks of included mud. A sharp but irregular contact separates the gypsite from the underlying brown clay. The gypsite lenses thin abruptly toward the edges and contain an increasing proportion of mud. In many cases the limit of gypsite of commercial grade is an approximately vertical plane. Solution cavities and sinks up to 3 feet in diameter that occur in the gypsite are a prominent feature of this deposit. Gypsite from this deposit is guaranteed to contain 60 percent gypsum. Two carryall scrapers are used for mining and stripping.

Koehn Lake Deposit (41)

A gypsite deposit of the lake-margin type exists in the southwest part of Koehn Dry Lake in sec. 28, T. 30 S., R. 38 E., MDM. Hess visited the area and described the occurrence soon after its discovery in 1909.[34] For a few years following the discovery this gypsite supplied a small calcining plant on the lake, but most of the production has been for agricultural purposes. G.W. Abel leased the deposit in 1926 and operated a grinding plant for a time. Later, C. A. Koehn produced gypsite on a small scale until his death; and Mrs. Koehn, now Mrs. Daly, has continued the enterprise.

The pit in operation during 1948 could be reached on good roads by driving 1½ miles south from Cantil and then 4 miles east. From here an unimproved track leads to the pit, a mile to the north. One or two feet of grass-covered soil lies on the gypsite which has been exposed in a pit 100 yards in diameter and up to 5 feet deep. The base of the deposit has not been exposed in the present workings. The gypsite, a white, fine-grained material having the consistency of packed snow, is cut by thin layers of clay and limonite that are parallel to the surface and a foot or two apart. Gypsite currently produced is guaranteed to contain 60 percent gypsum. The gypsite is mined and loaded into trucks with a Haiss creeper-model loader.

Lost Hills Deposits

Although Hess reported the occurrence of gypsite near Lost Hills in 1910,[35] mining was not undertaken until 1930. In 1934 H. M. Holloway Incorporated, now the largest producer of gypsite in California, began production near Lost Hills. In addition to the Holloway Company

[34] Hess, F. L. Gypsum deposit near Cane Springs, Kern County, California: U. S. Geol. Survey Bull. 430, pp. 417, 418, 1909.

[35] Hess, F. L., California, in Stone, R. W., and others, Gypsum deposits of the United States: U. S. Geol. Survey Bull. 697, pp. 65-67, 1920.

other gypsite producers at Lost Hills have been Handel and Son from 1941 to 1944, the Star Gypsum Company in 1943 and 1944, and the Theta Gypsum Company from 1941 to 1943.

The Holloway deposits [36] (43) which lie along the western side of the Lost Hills, are in secs. 3, 10, 11, 14, 15, 23, 24, 25, and 26, T. 26 S., R. 20 E., MDM. They may be reached from a road paralleling the Lost Hills that leaves U.S. Highway 466 about 3 miles west of Lost Hills. Gypsite bodies are scattered along the Lost Hills for a distance of about 4 miles.

The Lost Hills deposits possess some of the features of the lake margin type. Flat-lying lenses of gypsite, some as much as 20 feet thick, occur in slightly consolidated silty sand that contains lenses of gravel. Usually the gypsite lies within 3 feet of the surface, but some bodies are covered by 10 feet of alluvium. Many of the bodies are elongate and resemble in shape the channel deposits of McKittrick.

Gypsite near the centers of lenses is a nearly white, sugary material made up of interlocking plates of gypsum 0.005 inch in diameter. Calcite is not present, although there are a few quartz grains of the same size as the gypsum. Toward the edges the white gypsite grades into crusty gray silt containing streaks and spots of white gypsite up to $\frac{3}{16}$-inch in diameter. Lenses of sand and gravel are to be found within the gypsite, and in places gravel immediately underlies the gypsite. The gypsite bodies lie on clay in which mastodon bones have been found.[37] The gypsite at Lost Hills is thought to have formed in basins west of the Los Hills. At a later time uplift of the Temblor Range, which lies to the west, resulted in the cutting of channels through the gypsite bodies and their covering with alluvium. Carryall scrapers of 4-cubic yards capacity are used for mining.

McKittrick Deposits

Extensive gypsite deposits occur southwest of McKittrick in the Telephone Hills and also east of McKittrick on a hillside facing McKittrick Valley. Gypsiferous beds in the Maricopa shale and in the Tulare formation have been the source of much of the gypsite,[38] and there are channel deposits of gypsite also. When Hess visited the area in 1907 two companies had opened deposits, Abbott and Hickox in SW¼ sec. 30, T. 30 S., R. 22 E., and The California Gypsum and Mineral Company in S½ sec. 21, T. 30 S., R. 22 E. After being reorganized as the McKittrick Gypsum Company, the Abbott and Hickox property was productive through 1914. Others who reported production of gypsite in the same period or a little later were the McKittrick Extension Oil Company, La Corona Oil and Asphalt Company, and the Kern County Gypsum Company.

To judge from analyses published by Hess the gypsite mined prior to World War I was comparatively high grade material containing 85 percent or more gypsum. Perhaps because of its exhaustion, there was no production from 1922 until, in recent years, the Monolith Portland Cement Company mined gypsite during 1940 and 1941 for use in the manufacture of portland cement. Following the closing of their Panoche Hills deposit, Green and Collins produced gypsite in 1941 from a deposit 4 miles

[36] See also Kings County.
[37] H. M. Holloway, oral communication.
[38] Dibblee, T. W., Personal communication.

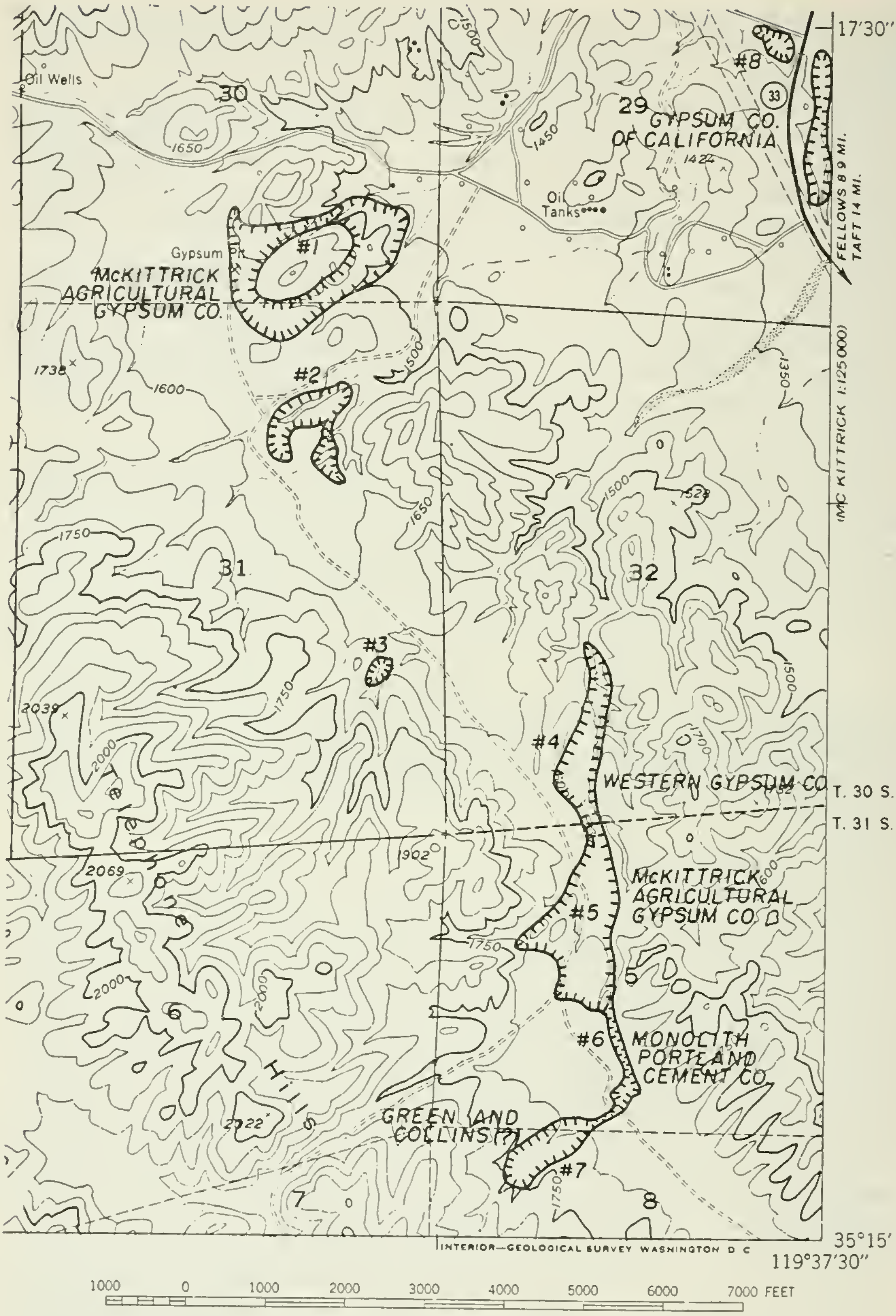


FIGURE 9. Index map showing locations of gypsite workings in the Telephone Hills.

southwest of McKittrick. The Gypsum Company of California worked a channel deposit that crossed State Highway 33 about 1 mile south of McKittrick. The Western Gypsum Company reported production in 1941, 1942 and from 1946 to the present. The McKittrick Agricultural Gypsum Company produced gypsite from 1947 to 1950.

McKittrick Agricultural Gypsum Company Deposit (45). This company operates under lease a deposit in sec. 21, T. 30 S., R. 22 E., that was worked by the California Gypsum and Mineral Company prior to 1910. It may be reached over an extension of E Street, McKittrick, which is east of the Southern Pacific station. An average of 3 feet of fairly compact, tan-colored gypsite lies on fine, unconsolidated sand. The company has worked deposits in the Telephone Hills also.

Telephone Hills Deposit (48). Gypsite occurs at intervals in a valley along the east edge of the Telephone Hills and about a mile west of State Highway 33. (See fig. 9). Workings begin just south of the McKittrick-Santa Margarita road, and extend southward for between 2 and 2½ miles. An unimproved dirt road that leaves the Santa Margarita road 1.1 miles west of its junction with State Highway 33 passes close to most of the gypsite workings. Gypsite has been mined under lease from Mr. Rankin of Bakersfield.

The most northerly workings (number 1, fig. 9) are on the flanks of a hill just south of the Santa Margarita road and east of a small marsh. This area was worked prior to World War I by Abbott and Hickox and recently by the McKittrick Agricultural Gypsum Company. During 1949 a pit 500 feet long, 50 feet wide, and 10 to 15 feet deep was dug at the base of the hill and close to the marsh. Crusty gypsite containing some calcium carbonate is exposed beneath 10 feet of stony soil. Gypsite extends from the north end of the pit eastward up the hill. East of the pit lenses of fairly hard, tan to white gypsite were mined over an area of several dozen acres. The gypsite grades downward into gravel containing selenite. Areas containing no gypsite are underlain by shale, although in one small area gypsite does rest on shale. The highest part of the hill northeast of the gypsite pit is composed of angular fragments of siliceous shale cemented by caliche.

The second group of workings (number 2, fig. 9) consists of shallow excavations on a low ridge between two washes and along their banks. This work was done some time ago, and little gypsite remains.

At the third location (fig. 9) an area of gypsite 100 yards in diameter has been stripped, and the base of the gypsite is exposed in the north side of the branch gully. There has been little production here. A few inches of stony soil covers 3 feet of fairly hard, fine-grained gypsite. Beneath the gypsite is about 6 feet of gravel composed of angular shale fragments. The gravel in turn rests on steeply dipping tan-colored clay shale.

The fourth location (fig. 9) is at the north end of an extensive group of workings. For a mile to the south the valley is so dug up with prospect trenches and littered with waste piles that the original distribution of the gypsite is obscure. The Western Gypsum Company has operated at location four. Here gypsite has been mined along the sides of a wash for about half a mile. On the west side of the wash up to five feet of slightly consolidated sand and gravel lie on 3 feet of gypsite that is soft, fine grained, and gray in color. Downward it grades into gray gypsiferous

sand and clay. Close to the east edge of the workings the wash has exposed the underlying material which is shale gravel containing clusters of interlocking selenite crystals. A trench, made apparently before the other workings, follows the east edge of the valley for about half a mile and extends south into location 5.

The most recent work in location 5 was done on the west side of the valley by the McKittrick Agricultural Gypsum Company, probably before 1948. Stripping on the lower hillsides has exposed gypsite that contains some calcium carbonate. In the gypsite area there is no sign of bedrock, but higher on the hillside above the gypsite there are outcrops of non-gypsiferous, siliceous Maricopa shale of Miocene age. These beds strike approximately north and are steeply dipping.

The Monolith Portland Cement Company worked a channel deposit in location 6. A crooked excavation about 20 feet deep that followed the channel has removed all the gypsite. On the walls is exposed gray gypsiferous clay covered by 10 feet of unconsolidated stony soil. At the south end the channel turns sharply west and terminates in the hillside workings of location 7.

Mining in location 7 may have been done by Green and Collins. No work has been done here for several years, and the access roads and loading chutes are in poor repair. Very little gypsite remains here. The gypsite apparently rested on sand and gravel.

At location 8 there are traces of excavations on both sides of State Highway 33, but there is little if any trace of gypsite remaining. The Gypsum Company of California worked a channel deposit here in 1945.

Packwood Canyon Deposit (47)

C.L. Fannin [39] has opened a deposit of gypsite in Packwood Canyon in sec. 9, T. 27 S., R. 18 E., MDM. It may be reached from a point on U.S. Highway 466 6.9 miles west of Blackwell's Corner over an improved gravel road four miles long. Gypsite has formed in a shallow basin where two intermittent streams join before flowing northeastward through a relatively steep and narrow valley. The bedrock is steeply dipping McDonald shale, a member of the upper Miocene Monterey formation.[40] In the basin from a few inches to 2 feet of silt lies on soft white gypsite that contains a little calcium carbonate. Downward the white gypsite grades through impure gray gypsite containing quartz grains and rock fragments to hard gypsiferous clay containing much calcium carbonate. Around the margins of the basin the streams have cut through the gypsite into stream gravel leaving a flat-topped island in the middle of the basin. In 1948 several acres had been stripped, and the gypsite was being prepared with a harrow for removal with a carryall scraper.

Kings County Deposits

Avenal Gap Mine[41] (50)

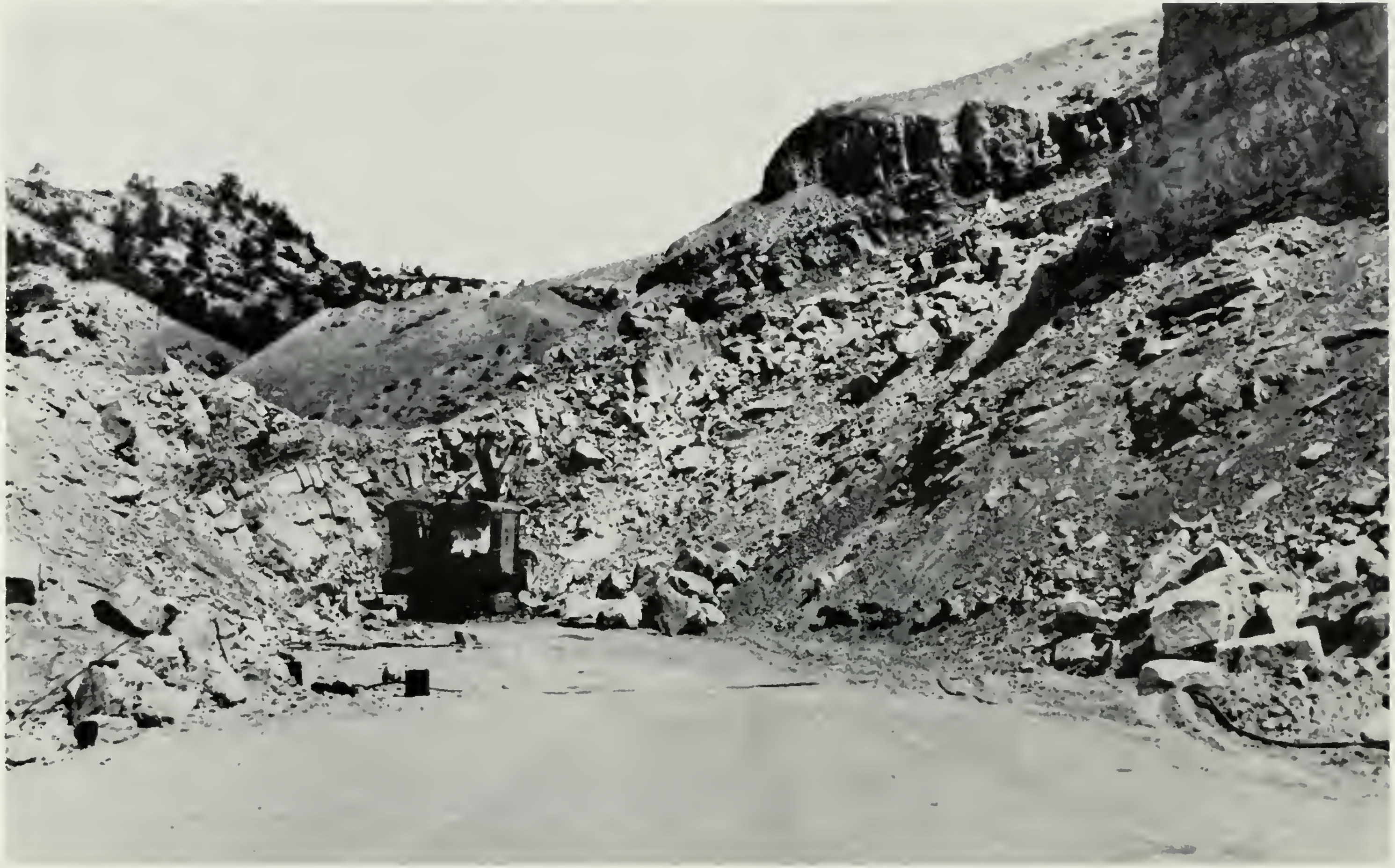
The Avenal Gap mine of H. M. Holloway, Inc., is in Kettleman Plain in secs. 2, 3, 11, T. 24 S., R. 18 E., MDM. It may be reached over a paved road 1.7 miles long that begins on State Highway 33 2.4 miles south of the junction of State Highways 33 and 41. Here a gypsite body, probably

[39] See also San Luis Obispo County.

[40] Heikkila, H. H., and MacLeod, G. M., Geology of the Bitterwater Creek area, Kern County, California: California Div. Mines, Special Rept. 6, plate 1, 1951.

[41] See also Kern County.

GYPSUM QUARRY, MONOLITH PORTLAND CEMENT COMPANY
Quatal Canyon. Clay beds above and beneath the gypsum are visible. Some clay interbedded with gypsum occurs half way up the face.



GYPSUM QUARRY, MONOLITH PORTLAND CEMENT COMPANY

Quatal Canyon. Gypsum occurs in the Quatal red clay member at the base of the Santa Margarita (upper Miocene) formation. Gypsum is in the face beyond the shovel. Over it lie the clay beds. The rocks on the smooth slope at the right center are either clay beds beneath the gypsum or a clay member within the gypsum. The light-colored beds covered with bushes in the upper left corner are coarse arkosic sandstone beds that overlie the Quatal red clay.

CHERT NODULE IN GYPSUM

Quatal Canyon deposit. A nodule is visible close to the hammer head. This nodule is more lenticular than most. These chert nodules are uniformly distributed through the lowest layers of the gypsum bed.

MONOLITH PORTLAND CEMENT COMPANY CRUSHING PLANT

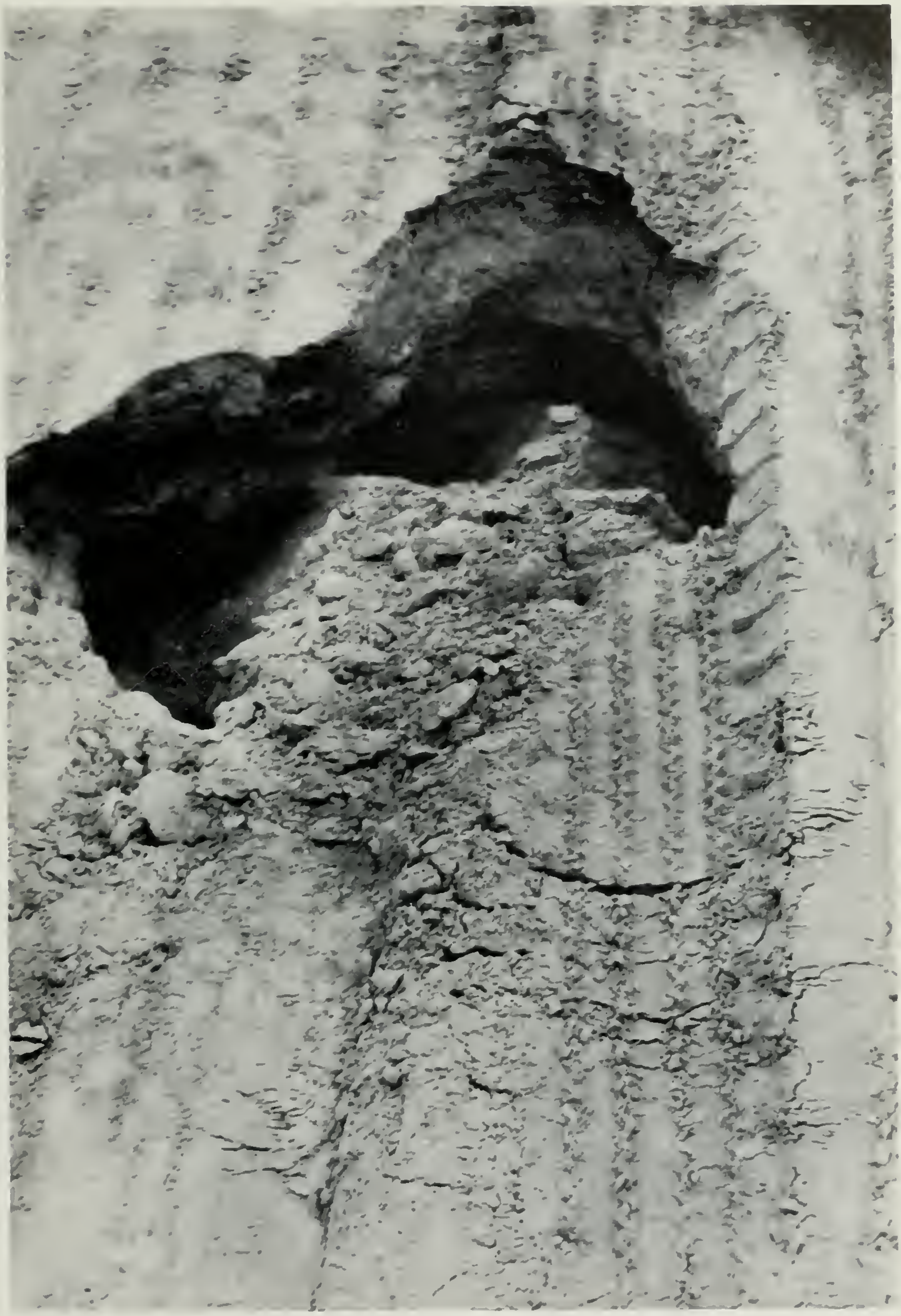
Quatal Canyon gypsum deposit. Shows the crusher, stock pile, and truck loading belt. The operating quarry is up the canyon and over the brow of the hill. A portion of the original quarry is visible at the extreme right. Shale lies on gypsum. Gypsum is trucked to Maricopa and shipped by rail to the company's portland cement plant at Tehachapi for use as a retarder.

CUDDY CANYON GYPSUM DEPOSIT

Near Frazier Park, Kern County. Lenses consisting of layers of light-colored brown gypsum up to 3 inches thick alternating with shale are interbedded with Miocene(?) sedimentary and volcanic rocks. *Photo by G. B. Oakeshott.*

GRIFFIN GYPSITE DEPOSIT

Tumey Gulch, Fresno County. Gypsite is ground in a hammer mill to remove lumps and loaded into trucks through the chute in the foreground. A prospect trench is on the hillside above the hammer mill.



SOLUTION CAVITY IN GYPSITE

Pacific Gypsite Company deposit, Kern Lake, Kern County. A solution cavity occurs in the pit floor. Note the track marks of the carryall scraper used to mine the gypsite.

SELENITE CRYSTALS FROM DANBY LAKE

Clusters of selenite crystals occur abundantly in the lake beds southwest of Saltmarsh Station.

of the lake margin type, lies with a sharp but irregular contact on sandy clay. Of a total average thickness of 6 feet, the upper 2 feet is a hard gray material composed of silt containing streaks and spots of finely divided gypsum. The lower 4 feet is fine-grained, soft, yellowish-white gypsite that contains a little calcium carbonate. Throughout the gypsite body lenses of unconsolidated sand are to be found; and there are tunnellike holes 1 or 2 feet in diameter, some of which are partly filled with sand. Two to three feet of sandy soil lies on the gypsite. The gypsite surface is irregular and is marked by what appear to be water-cut channels 1 foot wide and 9 inches deep. Carryall scrapers are used.

Los Angeles County Deposits

Palmdale Deposits (56)

Gypsite deposits half a mile southwest of Palmdale in NW¼ sec. 35, T. 6 N., R. 12 W., SBM have been described by Hess and by Simpson.[42] Evidences of open pit operations are also to be seen in SE¼ sec. 34, T. 6 N., R. 12 W., SBM. Mining was begun in 1892 by the Alpine Plaster Company, and in 1910 both this company and the Fire Pulp Plaster Company had mines and calcining plants at Palmdale. Operations were abandoned by 1915 when the easily obtainable gypsite had been exhausted. In 1948 the only traces remaining of the extensive operations were some partly filled open cuts.

The gypsite occurred on a low ridge south of Palmdale which may be reached from a track that turns west from U.S. Highway 6 just south of the railroad wye at Palmdale. Gypsite is associated with a gypsiferous shale member of the Escondido (Vasquez) formation that Simpson was able to trace for more than 8 miles east and west of Palmdale. Crystalline gypsum in beds an inch or two thick alternates with crumpled beds of brown shale. Gypsite formed beds 2 to 10 feet thick on the beveled edges of the gypsiferous shale.

Merced County Deposits

A. D. Sousa Deposit[43] (59)

In September A. D. Sousa was developing a gypsite deposit in NE¼ sec. 2, T. 12 S., R. 10 E., MDM. It may be reached by a steep but graded road that begins where the road running south from Los Banos turns southeastward to parallel the foothills. The gypsite is derived from the Kreyenhagen formation which in this area consists of beds of diatomite and marl that dip northeast toward the San Joaquin Valley. The marl is cut by closely spaced satin spar veins up to 4 inches thick.

The Sousa deposit lies on a flat-topped ridge underlain by the Kreyenhagen formation. Gypsite of uniform but comparatively low grade forms a flat-lying deposit on the beveled edges of the gypsiferous bedrock. It is planned to ship material assaying 40 percent gypsum.

Riverside County Deposits

Corona Deposits

Four miles south of Corona in the foothills of the Santa Ana Mountains there is a 2½-mile belt that contains gypsite of comparatively low grade. Although the gypsum content is only between 20 and 30 percent,

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[42] Hess, F. L., California, in Stone, R. W., and others, Gypsum deposits of the United States: U. S. Geol. Survey Bull. 697, pp. 75, 76, 1920.
Simpson, E. C., Mines and mineral resources of the Elizabeth Lake quadrangle, California: California Div. Mines Rept. 30, p. 412, 1934.

[43] See also Fresno County.

the material carries enough iron and lime to make it of value as a soil conditioner. An appreciable tonnage has been mined in Hagador Canyon, Gypsum (Main Street) Canyon, and Eagle Canyon and from the intervening ridges. Most of the mining took place from 1909 to 1919 and from 1924 to 1934; there have been no shipments since that time.

Among those who have reported production of gypsite are the Soil Tone Company and E. R. Nonhoff from Hagador Canyon; G. W. Lord from Gypsum (Main Street) Canyon; and the Amestoy Mineral Fertilizer Company, Natural Fertilizer Company, and Mineral Fertilizer Company from Eagle Canyon. Levi Katz and Floyd Shoemaker mined some gypsite from the Frazer property in Eagle Canyon during 1944.[44]

The deposit in Hagador Canyon (66) may be reached from a dirt road turning south from Chase Drive just east of Mangular Avenue, Corona. A foot path leads to the deposit, about a mile from the junction of Tin Mine and Hagador Canyons. A road from the south end of Main Street formerly led to the Gypsum Canyon deposit (65), but it is no longer passable for vehicles. The deposits have been opened by small cuts, shallow pits, and short tunnels.

In Gypsum and Hagador Canyons the country rock is a hard gray, blocky andesite porphyry of the Santiago Peak volcanics that has been cut by shear planes that strike northeast and dip steeply northwest. Along the sheer planes are zones of hydrothermal alteration where the porphyry has been kaolinized and stained with limonite. Closely spaced satin spar veinlets run in all directions through the altered rock. Apparently both the gypsum-bearing altered rock and gypsite derived from it were mined.

San Luis Obispo County Deposits

Carrisa Mine (95)

The Carrisa gypsite mine, located in sec. 21, T. 30 S., R. 20 E., was operated by V. C. Hatley and C. L. Fannin during 1947 but was idle in December 1948. The mine may be reached from the road to Soda Lake that leaves State Highway 178, 18 miles west of McKittrick. The gypsite here has been derived from the upper Pliocene McKittrick formation.

The deposit consists of at least three elongated, flat-lying lenses of gypsite that lie along an approximately east-west line extending for three quarters of a mile from the lower slope of the Temblor Range toward the Carrizo Plain. The easternmost and largest lens is about 500 yards in diameter, while the most western and smallest is less than 100 yards wide. Between the three lenses there is little if any gypsite.

Gypsite crops out in the higher parts of the deposit, but on the lower slopes it is covered with 12 to 14 inches of stony soil. In general the upper 2 feet of the gypsite is a relatively clean, earthy, cream-colored material that grades downward into gypsite that contains sand and fine-grained gravel. In places the sandy gypsite rests on gravel containing $\frac{1}{4}$-inch selenite fragments, but in other places at least locally it lies on soft clay shale.

Shandon Deposit (97)

The Shandon deposit, which has been operated under lease by C. E. Vanderford and is now worked by the owner, L. L. Styles, is in sec. 21, T. 26 S., R. 15 E., SBM, just east of Shandon on U. S. Highway 466.

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[44] Tucker, W. B., and Sampson, R. J., Mineral resources of Riverside County: California Div. Mines Rept. 41, p. 168, 1945.

This is a lenticular deposit of the lake margin type 4 feet thick, 500 yards long, and 200 yards wide. At the end of 1948 gypsite had been mined from the north side of the highway, but it exists on the south side also. There is no overburden except a few inches of earth, and the deposit lies on clay. The material mined, which is guaranteed to contain 70 percent gypsum, is a tan-colored, earthy material that contains an appreciable amount of calcium carbonate. A test cut just north of the lens encountered gray silt containing streaks and spots of fine-grained gypsum.

Ventura County Deposits

Fillmore Deposit (106)

A gypsite deposit formerly worked by the Sunset Plaster and Cement Company of Fillmore is on Oak Ridge in SE¼ sec. 7, T. 3 N., R. 19 W., SBM. An old road impassable for vehicles runs to the deposit from State Highway 28 at the point where the highway joins Grimes Canyon. Gypsite has not been mined since 1914. The principal mine opening is an open cut with face about 200 feet long and 100 feet high, and there are at least four smaller cuts.

Bedrock here is the Modelo shale.[45] "Chalky," diatomaceous, organic, and clay shales of this formation dip steeply southwest. Near the deposit the organic shale has been burned, perhaps by spontaneous combustion, to a vesicular, brick-red material resembling lava. Satin spar veinlets up to an eighth of an inch wide cut the shales. Pockets of gypsite have formed on the outcrop and extend as much as 30 feet into the bedrock down the dip. Little gypsite remains.

ORIGIN OF GYPSUM

With the exception of gypsite and some hydrothermal vein and replacement deposits of minor economic interest, gypsum deposits are believed to be chemical precipitates that have formed from saline solutions. Playa deposits undoubtedly are, but the processes involved in the formation of the thick beds of rock gypsum are not readily apparent. No entirely satisfactory hypothesis for the origin of such deposits has been proposed.

When saline water is evaporated, in general the least soluble salts precipitate first and leave the more soluble ones in the mother liquor. The very soluble bittern salts, which are usually complex salts, precipitate only after complete evaporation. The precipitation of a salt is greatly influenced by temperature and the concentration of other salts in the solution. The behavior of systems of mixed salts has been determined for only a comparatively small number of systems.

Theoretically the evaporation of a body of saline water results in separate layers of limestone, gypsum, common salt and bittern salts that are deposited in inverse order of their solubility, but the complete sequence rarely if ever occurs in nature. Bristol Lake possesses some of the ideal features, for gypsum and salt occur in separate parts of the lake, while the brine associated with the salt is high in calcium chloride.[46]

Rock gypsum is, however, greatly different from the loosely knit mesh of large gypsum crystals mixed with salt and silt that characterizes the

[45] Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, California: U. S. Geol. Survey Bull. 753, p. 61, 1924.
[46] Gale, H. S., Geology of the saline deposits of Bristol Dry Lake, San Bernardino County, California: Calif. Div. Mines Special Rept. 13, 21 pp., 1951.

playa deposits. Except for the Avawatz Mountains deposits the California rock gypsum deposits are not associated with salt or other salines. Limestone is not present except in the pre-Tertiary deposits although most specimens contain 1 percent or less of calcite as scattered grains 0.001 inch in size. Moreover, the gypsum itself of the California deposits is of great uniformity and contains no more than traces of salt and other very soluble salines. Branson [47] has calculated that 0.7 feet of gypsum would be deposited from 1000 feet of sea water evaporated to the saturation point of sodium chloride. Even if sea water were first concentrated to the saturation point of gypsum and then evaporated it would require a basin 11,500 feet deep to deposit 40 feet of pure gypsum without salt. Apparently either the water from which thick gypsum deposits precipitated contained only calcium sulfate or else in some way it remained unsaturated with the other salts normally found in saline water.

In order to explain the formation of gypsum in basins of reasonable depth a number of hypotheses have been proposed. The bar theory of Ochsenius,[48] which supposes a basin separated from the open sea by a bar of sufficient height to allow fresh supplies of sea water to come in, explains the formation of salts but not their separation. Branson [49] imagined a series of connecting basins like those of a solar salt works in which salts of differing solubility would be separately precipitated. Others have suggested the leaching of thin deposits and the subsequent reprecipitation of gypsum in deeper basins,[50] or the mechanical concentration by currents of already precipitated gypsum.

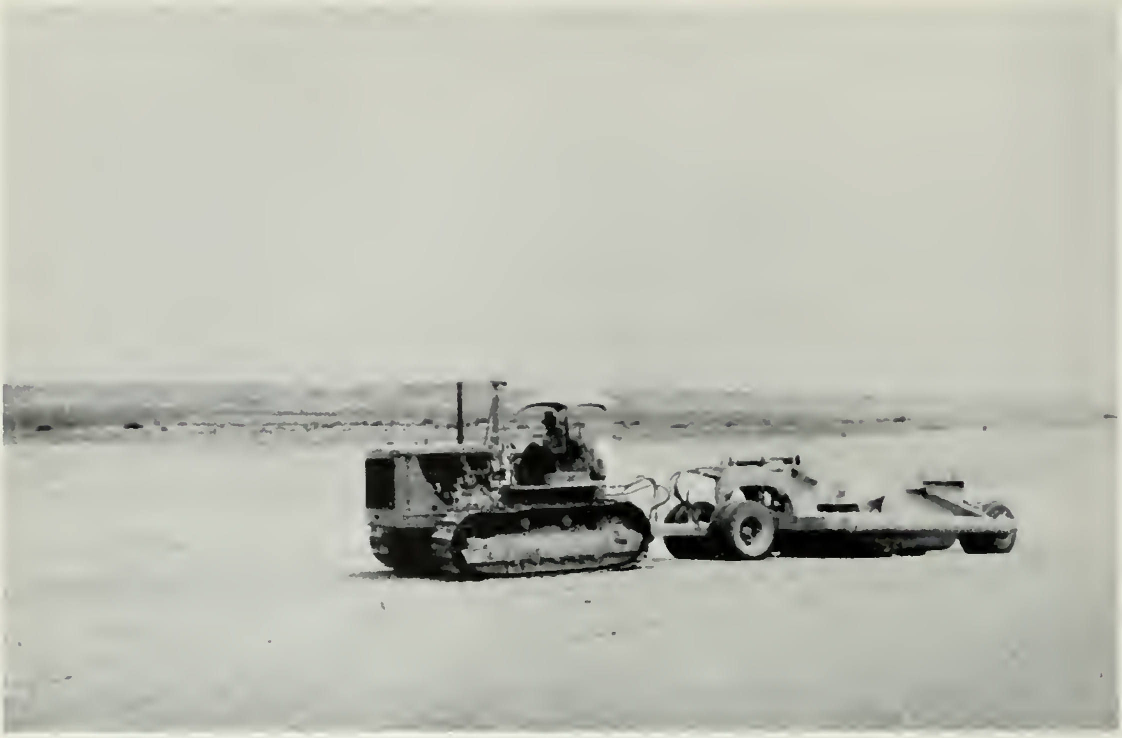
Branson's modified bar hypothesis seems to fit some of the California deposits, perhaps the Death Valley deposits most clearly. Assuming climatic conditions slightly more humid than those of today, the region was probably supplied with saturated saline water from which the slightly soluble calcium carbonate had already been precipitated. Both the China Ranch and Avawatz Mountains deposits formed in temporary saline lakes that had restricted outlets. Evaporation caused the water to be saturated with gypsum but not with sodium or potassium salts. These more soluble salts, still in solution, escaped through the outlet and eventually reached the floor of Death Valley. Although it is difficult to reconstruct the prefaulting conditions at the Avawatz Mountains deposits, the gypsum and salt were probably separated by sediments. After the gypsum precipitation ceased and the gypsum was buried, salt precipitating conditions prevailed.

The modified bar hypotheses applies also the Cuyama Valley deposit. According to Dibblee [51] the sediments that contain the gypsum are nonmarine sediments that grade northwestward into marine sediments. Perhaps a temporary basin close to the shore was fed by pre-concentrated saline water from the land area to the southeast. The brown shales that enclose the gypsum suggest such a lake. In this case the overflow of water high in soluble salts flowed into the sea and was lost.

[47] Branson, E. B., Origin of thick gypsum and salt beds: Geol. Soc. America Bull., vol. 26, p. 232, 1915.
[48] Grabau, A. W., Principles of salt deposition, pp. 128-130, New York, McGraw-Hill Book Co., 1920 (summary in English).
[49] Branson, E. B., op. cit. pp. 231-242.
[50] Wilder, F. A., Some conclusions in regard to the origin of gypsum: Geol. Soc. America Bull., vol. 32, pp. 385-394, 1921.
[51] Dibblee, T. W., Jr., Personal communication.

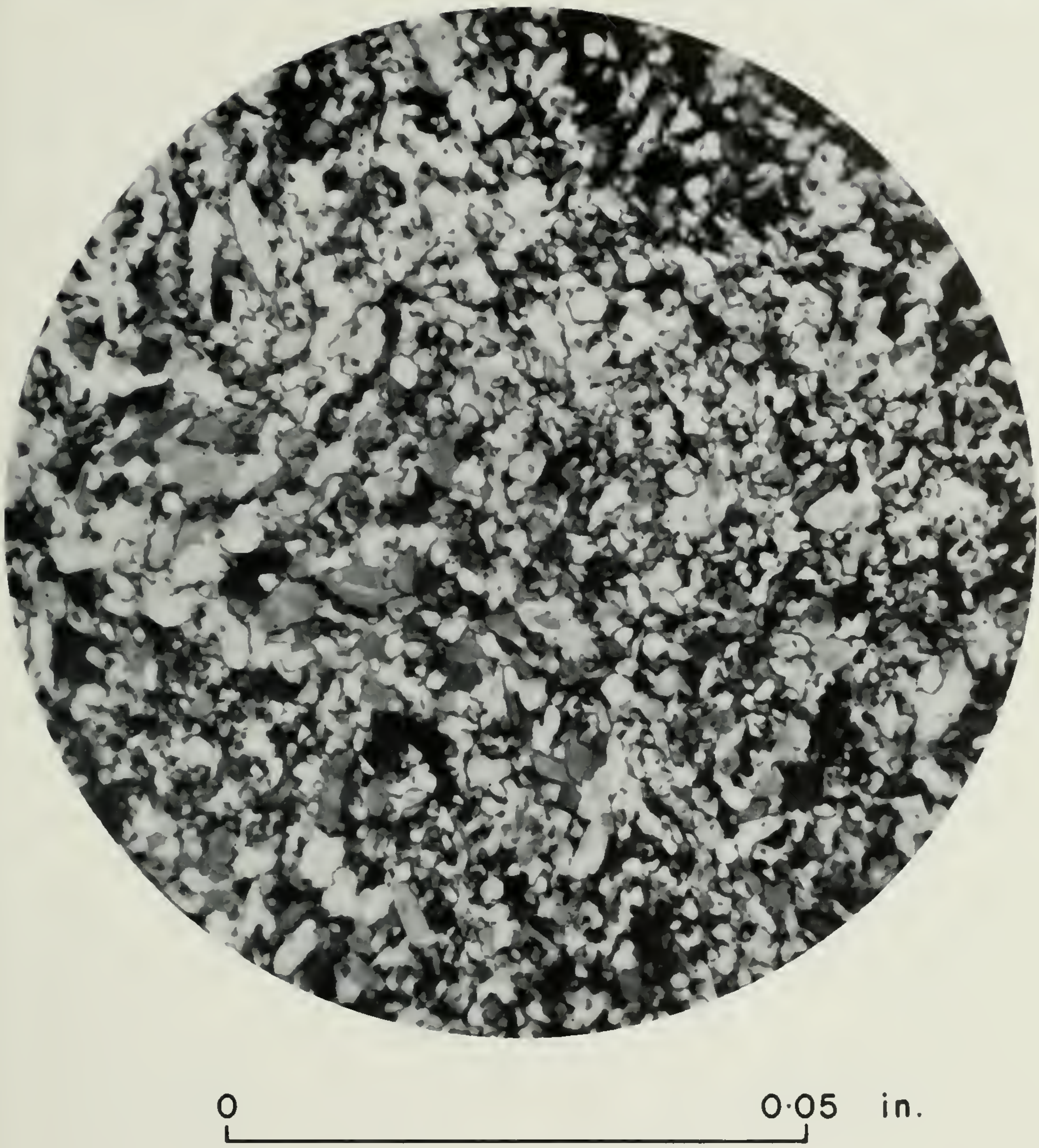
LOST HILLS GYPSITE MINE

Kern County. Loading gypsite with carryall scrapers. These trucks haul the gypsite to farms in the San Joaquin Valley and as far north as Livermore.



A. AVENAL GAP GYPSITE MINE
Kings County. Mining gypsite with carryall scraper. *Photo by J. W. Vernon.*

B. CARISSA GYPSITE MINE
Carrizo Plain, San Luis Obispo County. Truck loading chute.



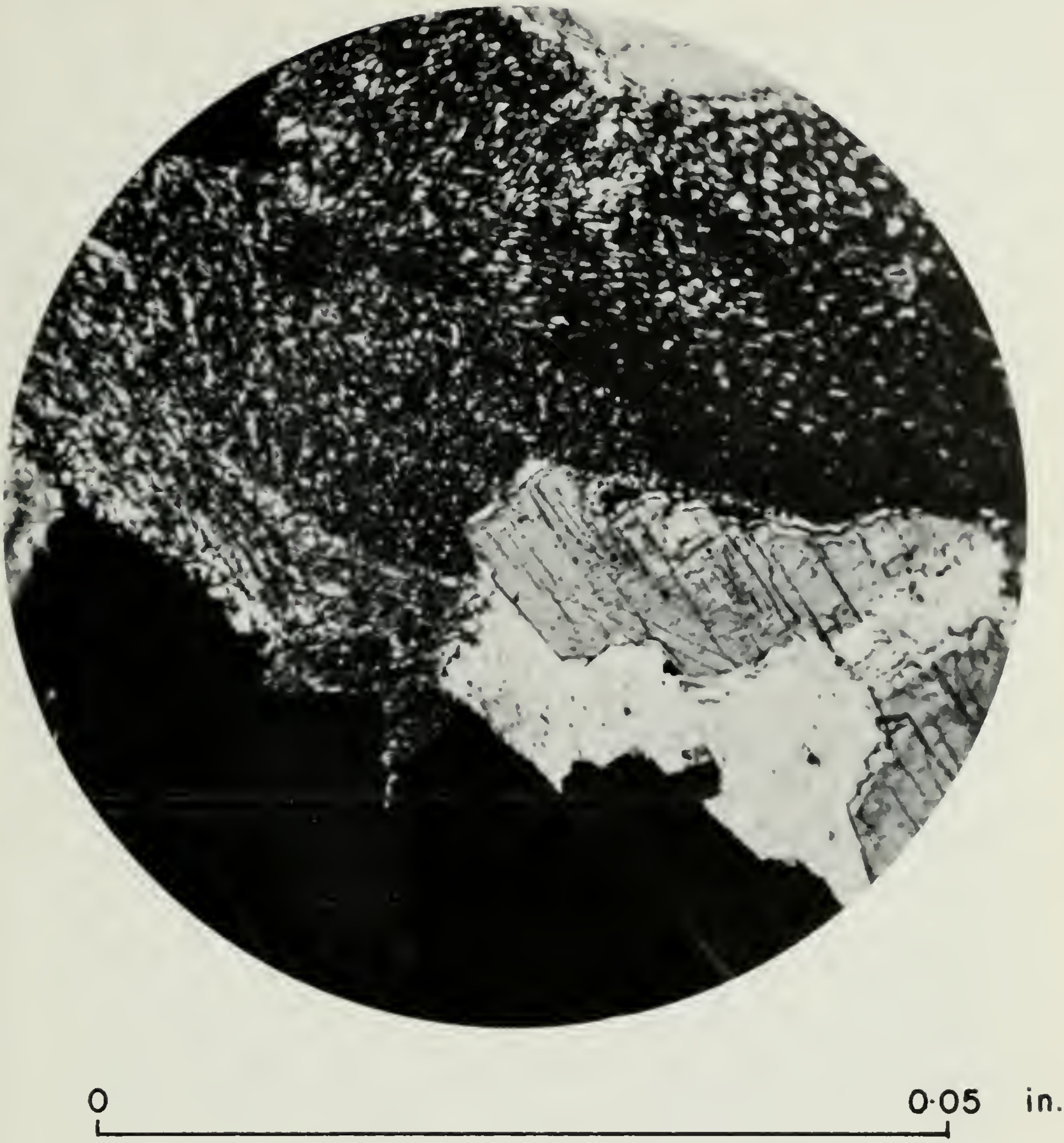
PHOTOMICROGRAPH OF ALABASTER
Exhibiting granoblastic texture. Frenchman's Point deposit, Cuyama Valley. Crossed nicols.

PHOTOMICROGRAPH OF GYPSUM
Exhibiting fibrous texture. Fish Creek Mountains deposit. Crossed nicols.

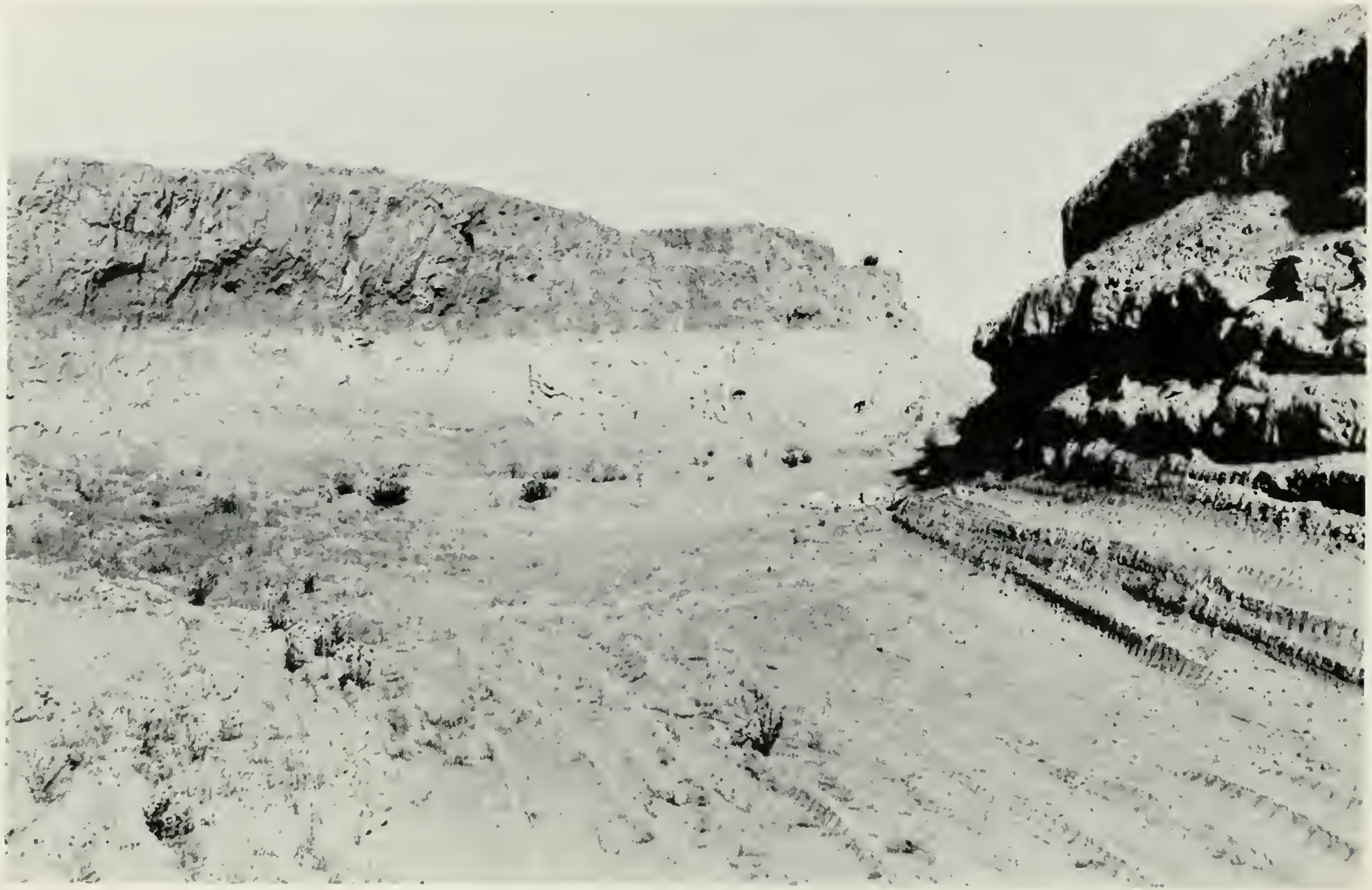
PHOTOMICROGRAPH OF PORPHYRITIC GYPSUM
Utah Construction Company quarry, Little Maria Mountains. Large euhedral to subhedral gypsum crystals in a granoblastic groundmass. Crossed nicols.

PHOTOMICROGRAPH OF GYPSUM AND ANHYDRITE

Utah Construction Company Quarry, Little Maria Mountains. Fibrous gypsum fills cracks between anhydrite that has well developed polysynthetic twinning in two directions. Plain light.



PHOTOMICROGRAPH OF FIBROUS GYPSUM
And anhydrite, Utah Construction quarry, Little Maria Mountains. Crossed nicols.



MONOLITH WORKINGS
Abandoned gypsite workings of Monolith Portland Cement Company in the Telephone Hills. The material was mined for Portland cement retarder in 1940.

With the Fish Creek Mountains deposit the modified bar hypotheses is less clear. The absence of any great quantity of fine sediments is noticeable, while there is a very great thickness of fanlike conglomerate. Perhaps a structural basin was formed which was partially filled with detrital material from the surrounding highland of granitic and metamorphic rock. The abruptness of the transition from conglomerate to gypsum suggests that the basin was quite suddenly filled with saline water already concentrated to the saturation point of gypsum. Either the supply of clastic material almost entirely ceased while the more than 100 feet of gypsum formed, or else the gypsum precipitated extremely rapidly compared to the rate of accumulation of the arkosic sandstone that preceded and succeeded the gypsum-precipitating interval. Because large deposits of salt have not been found in the Salton Sea region it seems likely that most of the salt associated with the gypsum escaped in solution, perhaps to the Gulf of California.

A lagoon origin for the pre-Tertiary deposits is not obvious because the evidence of the topography has disappeared and even the relative ages of the rock units are obscure. Harder [52] believes that these deposits formed in the deep waters of saline lakes in which uniform conditions of sedimentation prevailed. Presumably the region was later subjected to mild regional metamorphism that changed any calcium sulfate existing as gypsum to anhydrite, shale to schist, sandstone to quartzite, and recrystallized the limestones. Mixtures of schist and gypsum resulted from the metamorphism of impure gypsum and gypsiferous clay. A typical specimen of impure gypsum from a waste layer in the Utah Construction Company quarry consists of lenses of gypsum ¼ to 1 inch long separated by green layers of micaceous minerals that are broken and bent around the gypsum lenses. Small structures in gypsum containing argillaceous impurities at the Avawatz Mountains are much the same.

The major difference between the pre-Tertiary and the Tertiary gypsum deposits is the character of the associated sediments. The Tertiary deposits originated in temporary saline lakes that formed in areas that were land before and after gypsum deposition, whereas the pre-Tertiary deposits are associated with marine sediments, and gypsum formation was preceded and succeeded by marine conditions.

It is possible, although less likely, that in the pre-Tertiary deposits the gypsum zones may be certain limestone beds that have been replaced by calcium sulfate. The magnesium of the tremolite, which is widely distributed in both the gypsum zones and the green schistose rocks, could have been introduced at the same time as the calcium sulfate.

Gypsum-Anhydrite Problem

Gypsum is almost always associated with anhydrite, and in most deposits, including those in California that have been developed in depth, gypsum grades downward into anhydrite. In the extensively explored deposits of New York, Michigan, and Ohio this gradational contact is parallel to the present surface and at a depth of from 100 to 300 feet.[53] As far as can be told from the limited data available the same conditions are true in the Fish Creek Mountains deposit. In the Little Maria Moun-

[52] Harder, E. C., The gypsum deposits of the Palen Mountains, Riverside County, California: U. S. Geol. Survey Bull. 430, pp. 413, 414, 1910.
[53] Newland, D. H., Relation of gypsum supplies to mining: Am. Inst. Min. Met. Eng., Trans. vol. 66, pp. 92-94, 1922.

tains where gypsum and anhydrite are more intimately mixed, the proportion of gypsum is proportional to the extent of open fracturing in the enclosing rocks.[54]

There has been lack of agreement as to whether calcium sulfate precipitates as anhydrite and is hydrated by ground water or whether gypsum is converted to anhydrite by heat and/or pressure when it is buried. The conditions under which gypsum and anhydrite precipitate have been studied in the laboratory. Posnjak [55] concluded that the widely accepted data of Van't Hoff are incorrect. His experiments showed that from a solution of calcium sulfate in water gypsum precipitates below 42° C (108° F) and anhydrite above that temperature. The presence of other salts lowers this temperature. When sea water evaporates at 30° C about half of the calcium sulfate present precipitates as gypsum, and when the salt content has risen to 4.8 times normal, the calcium sulfate remaining precipitates as anhydrite. He concludes that if a deposit of anhydrite is assumed to have formed at less than 42° C at least part of it must be secondary. That actually some anhydrite is primary is suggested by the presence of small quantities of anhydrite among the minerals of playas.[56]

Microscopic Evidence. Among the first to apply the petrographic microscope to the gypsum-anhydrite problem and one of the few to describe these minerals in thin section is A.F. Rogers.[57] From a study of specimens of gypsum and anhydrite from many parts of the United States he concludes that most gypsum is a hydration product of anhydrite. His conclusions are based not only on the relations between gypsum and anhydrite as seen in thin section but on differences of the gypsum's texture as well.

Gypsum in Thin Section. For convenience the textures recognizable in the California specimens are summarized here. The first, corresponding to Rogers' hydration structure, consists of intricately interlocking equidimensional anhedra that range from 0.002 to 0.02 inch in size. Optically the grains are unoriented, and each grain has a narrow extinction angle. A second texture megascopically is a granular aggregate of grains 0.05 inch in size. Under the microscope each grain is seen to be composed of minute, nearly parallel fibers of gypsum. A third texture consists of poorly defined areas, often filled with anhydrite inclusions, that have a wide extinction angle. Such grains have lower relief and birefringence than do those of the first texture described.

In the present study Rogers' evaportion structure, or the texture of gypsum formed by direct precipitation from saline water, was not recognized. His illustration shows large interlocking euhedral and subhedral crystals. It is a photomicrograph of gypsum from a deposit near King City; one of the few that Rogers believes to be primary. It is to be noted that while the specimen from Mule Shoe Ranch, described earlier, does contain a few euhedral crystals the texture is predominately the hydra-

[54] Conway, C. L., Personal communication.

[55] Posnjak, E., The system, $CaSO_4$-H_2O: Am. Jour. Sci., 5th ser., vol. 35-A, pp. 247-272, 1938.

Deposition of calcium sulfate from sea water: Am. Jour. Sci., vol. 238, pp. 559-568, 1940.

[56] Hanks, H. G., On the occurrence of hanksite in California: Am. Jour. Sci., 3rd series, vol. 37, p. 66, 1889.

[57] Rogers, A. F., Notes on the occurrence of anhydrite in the United States: School of Mines Quarterly, Columbia Univ., vol. 36, pp. 123-142, 1915.

tion kind. The Quatal Canyon gypsum also contains a small proportion of euhedral to subhedral crystals.

Conclusions. The present study confirms Rogers' conclusions that most gypsum is a replacement of anhydrite. The veinlike penetrations of gypsum into anhydrite and the corroded remnants of anhydrite present in many specimens of gypsum show this.

With regard to the texture of gypsum, it is unlikely that Rogers' hydration structure is diagnostic of gypsum derived from anhydrite. In the Little Maria Mountains the gypsum that actually penetrates between anhydrite grains has fibrous rather than hydration texture, while pure gypsum in that area is in well-developed euhedral crystals. It is possible that the hydration texture is caused by recrystallization because there is a striking resemblance between it and that of marble or metamorphic quartzite.

The significance of the fibrous texture is not clear. The Fish Creek Mountains gypsum, which is fibrous, is tightly folded although the enclosing rocks are not. Perhaps fibrous gypsum forms when the gypsum recrystallizes under stress. Impure gypsum from Quatal Canyon is fibrous, and so is pre-Tertiary gypsum that contains schist, limestone, or anhydrite. Possibly stress was caused by the interference of the impurities with the growth of the gypsum crystals.

PART 2

MINING, PROCESSING AND MARKETING OF GYPSUM

PART 2

CONTENTS

MINING

History of Gypsum Production in California

At one time or another most of California's gypsum deposits have attracted miners, and the records contain the names of scores of operators who worked them. Few of these enterprises, however, endured for longer than 5 years, and of these not many contributed a significant proportion of the current production. The California gypsum industry has, however, from the very beginning been dominated by a major producer who, with one or two competitors, accounted for three quarters of the production at the time they were active. It is possible to define five overlapping periods during which the gypsum industry was centered in one deposit and one company. In general the end of a period came when the dominating deposit became exhausted or was no longer able to supply the constantly rising demand for gypsum.

The first period, which includes the very beginning of the industry in California, came to an end about 1900. Production average about 2500 tons a year. It has been stated [58] that the earliest use for gypsum in California was for agriculture. As early as 1875, however, the Golden Gate Plaster Mill of Lucas and Company was in operation at San Francisco. Prior to that time calcined gypsum was brought into California by ship. John Lucas, who had been a calciner for a New York firm, came to California in 1865 and began experimenting with crude gypsum from a number of deposits. Before 1880 Lucas and others were importing crude gypum from Lower California, probably San Marcos Island. Then in 1880 Lucas and Company leased a deposit near Point Sal, Santa Barbara County and developed the Point Sal mine, the first important California gypsum producer. The gypsum, which occurred as bunches and veins in clay shale, was mined from tunnels and loaded on ships at a landing near Point Sal, a mile or two from the mine. An estimated thousand tons were mined in the first four years. The mine was closed, however, in 1889, and by 1895 the workings were inaccessible. The Lucas Company continued until about 1900 when fire destroyed the mill in San Francisco.

Meanwhile in 1884 agricultural gypsum was being ground at a mill in Los Angeles. In 1890 and for several years after that Captain Fauntleroy mined agricultural gypsum from the Cottonwood Creek deposit near Bakersfield. Hall, Doverall, and Lavelle in 1892 opened a deposit near Coalinga which produced agricultural gypsum until about 1897. In addition a number of other deposits which later assumed some importance were first worked in the 1890's.

The second period, from 1900 to about 1908, is largely the history of the Alpine Plaster Company with mines at Palmdale. The total California production had by then risen to an average of 10,000 tons a year. The Alpine Plaster Company as early as 1892 had a calcining plant in Los Angeles for treating crude gypsum mined at Palmdale. The output of the Los Angeles mill for a single month in 1893 was as follows: [59]

	Tons	Value per ton f.o.b. Los Angeles
Plaster of Paris	15	$18.00
Wall plaster	20	$11.00
"Fertilizer"	100	$7.00

[58] Santmyers, R. M., Development of the gypsum industry by states: U. S. Bur. Mines Inf. Circ. 6173, pp. 6-9, 1929.
[59] Gypsum: California Min. Bur. Rept. 12, p. 324, 1893.

GYPSUM PRODUCTION IN CALIFORNIA

Year	Short tons	Value	Average value	Year	Short tons	Value	Average value
1887	2,700	$27,000		1917	30,825	$56,840	
1888	2,500	25,000		1918	19,695	37,176	
1889	3,000	30,000	$10.00	1919	19,813	50,579	$2.60
1890	3,000	30,000		1920	20,507	92,535	
1891	2,000	20,000		1921	37,412	78,875	
1892	2,000	20,000		1922	47,084	188,336	
1893	1,620	14,280		1923	86,410	289,136	
1894	2,446	24,584	9.70	1924	25,569	53,210	2.58
1895	5,158	51,014		1925	107,613	172,444	
1896	1,310	12,580		1926	114,868	211,337	
1897	2,200	19,250		1927	94,630	292,090	
1898	3,100	23,600		1928	104,790	200,567	
1899	3,663	14,950	6.87	1929	140,844	396,951	2.43
1900	2,522	10,088		1930	116,865	243,507	
1901	3,875	38,750		1931	88,854	199,198	
1902	10,200	53,500		1932	46,867	93,818	
1903	6,914	46,441		1933	59,235	120,451	
1904	8,350	56,592	5.26	1934	58,149	113,606	2.03
1905	12,859	54,500		1935	70,833	151,807	
1906	21,000	69,000		1936	143,549	282,703	
1907	8,900	57,700		1937	186,160	384,431	
1908	34,600	155,400		1938	161,996	327,821	
1909	30,700	138,176	4.31	1939	219,672	437,343	1.99
1910	45,294	129,152		1940	314,843	599,944	
1911	31,457	101,475		1941	432,784	854,184	
1912	37,529	117,388		1942	425,268	791,892	
1913	47,100	135,050		1943	475,967	916,883	
1914	29,734	78,375	2.53	1944	558,488	949,833	2.00
1915	20,200	48,953		1945	442,133	954,696	
1916	33,384	59,533		1946	618,007	1,431,884	
				1947	811,798	1,996,157	
				1948	962,038	2,354,390	2.45
				1949	753,581	1,852,452	

GYPSUM PRODUCTION (SHORT TONS) BY COUNTIES

Year	Fresno	Imperial	Inyo	Kern	Kings	Los Angeles	Riverside	San Benito	San Bernardino	San Luis Obispo	Santa Barbara	Ventura
1880-1889									[1]			
1890												
1891												
1892												
1893												
1894	500					1,134	50	762				
1895	600					3,790	18	750				
1896	50					960		300				
1897						1,900		300				
1898	100					2,500		500				
1899						3,563		100				
1900						2,500						
1901						3,500	300					
1902				1,000			100					
1903				1,000		5,914						
1904												
1905				1,350		11,500						
1906						21,000						
1907				1,000		7,500						
1908				500		12,000		2,000	20,000			
1909				1,700		10,000	400	6,000	12,500			
1910				1,675				12,000	31,519			
1911				853				10,000	20,584			
1912				8,479				8,000	21,000			
1913				10,000			1,000	11,000	25,000			
1914				82			5,350	7,000	17,332			
1915				[1]			3,450		[1]			
1916			[1]				4,220		[1]			
1917			[1]				1,923		[1]			
1918									[1]			
1919							200		19,613			
1920												
1921				[1]								
1922		[1]										
1923		[1]		[1]								
1924		[1]					[1]					
1925		[1]					[1]					
1926		[1]		[1]			[1]					
1927		[1]		[1]			[1]					
1928		[1]		[1]			[1]					
1929		[1]					[1]					
1930	[1]	[1]		[1]			[1]					
1931	[1]	[1]					[1]					
1932	[1]	[1]					[1]					
1933	[1]	[1]					[1]					
1934	[1]	[1]					[1]					
1935	19,899	[1]					[1]					
1936	[1]	[1]					[1]					
1937	[1]	[1]					[1]					
1938	[1]	[1]					[1]					
1939	[1]	[1]		[1]			[1]	[1]				
1940	[1]	[1]		70,043			[1]	[1]				
1941	[1]	[1]		112,088			[1]					[1]
1942		[1]		156,104			[1]	[1]				[1]
1943		[1]		250,989			[1]					[1]
1944		[1]		292,306			[1]					[1]
1945		[1]		[1]			[1]	[1]				[1]
1946	[1]	[1]		268,162			[1]	[1]				[1]
1947	[1]	[1]		352,977 [2]	[1]		[1]			[1]		[1]
1948	[1]	[1]		271,908	[1]		[1]			[1]		[1]
1949	[1]	[1]		202,904	[1]		[1]			[1]		[1]

[1] Production not disclosed.
[2] Includes a small tonnage from Kings County.

A much larger mill was built at Palmdale in 1901. Two oil-fired calcining kettles had a capacity of 40 tons of stucco a day.

A contemporary producer was the Fire Pulp Plaster Company which manufactured a special plaster containing stucco mixed with clay and asbestos fiber. In 1904 this company opened a deposit in Charlie Canyon north of Castaic. After floods washed out the access road this deposit was abandoned, and operations were transferred to Palmdale. Both the Alpine Plaster Company and the Fire Pulp Plaster Company were active in Palmdale in 1909, but by 1915 the high grade gypsum was exhausted and operations were abandoned.

The third period, which lasted until 1919, covers the life of the Pacific Cement Plaster Company which worked the deposits on the north side of Bristol Lake near Amboy, a station on the main line of the Santa Fe railroad. California's yearly production of gypsum fluctuated widely but reached an average of 35,000 tons a year. The production from Bristol Lake marks the first shift of the gypsum industry to the southeastern desert regions.

The Pacific Cement Plaster Company commenced operations in 1906, and by 1907 a mill was in operation at Amboy. The operation consisted of scraping away the thin, salty overburden, loosening the gypsum with plows, and scraping the gypsum to chutes for loading into tram cars. At first horses were used to pull the cars from the deposit to the mill at Amboy, a distance of 2 miles. Cloudman,[60] who visited the plant during the winter of 1913-1914, reported that horses had been replaced by a small steam locomotive. At the plant the gypsum was first crushed and then washed to remove a considerable content of salt and dirt. At that time output was 100 tons a day of hardwall plaster and ''cement plaster'' used by southern California portland cement plants.

About 1916 the original mill at Amboy was abandoned and replaced with a new plant approximately 2 miles southeast of Amboy. This mill contained a rotary drier in which the gypsum received a preliminary treatment. The drying caused the gypsum crystals to decrepitate and release much of the fine silt which was swept out of the drier with the draft. The material produced by the drier contained about 94 percent gypsum. About half of the output was sold to the portland cement plants at Victorville and Oro Grande for use as retarder, one-third as agricultural gypsum, and the remainder was made into calcined products.

On September 2, 1919 the Consolidated Pacific Cement Plaster Company, as the operation had been known for several years, sold out to the United States Gypsum Company; and the third period came to an end.

A number of other deposits were active during the third period and contributed a significant portion of the production at that time. There seems to have been two separate operations at the Mule Shoe ranch property. Some gypsum was mined before 1893, but the main period of production was from 1908 to 1914. J. F. Dunne operated one quarry, and at least part of the output was made into plaster at Santa Cruz. Dunne reported in 1915 that the quarry had been closed for some time. Also from about 1909 to 1915 the Lyons Gypsum Company was shipping gypsum from King City, and at least some of it came from a leased deposit near the Dunne Quarries. In 1916 the Lyons Company bought the Dunne

[60] Cloudman, H. C., et. al., San Bernardino County: California Min. Bur. Rept. 15, pp. 869-870, 1916.

Quarries but there was no further production reported. Much later two other companies produced agricultural gypsum from the Mule Shoe Ranch deposit. The Triangle Fertilizer Company mined a few hundred tons from 1938 to 1942, and the Monterey Gypsum Company was a producer during 1944 and 1945.

Another competitor worked the Koehn Lake deposit which was discovered in 1909.[61] A plaster mill built in 1910 was operated until 1913 by the Crown Plaster Company and in 1913 by the Gypsum Mining Company. Apparently the deposit remained idle until 1926. Since then C. A. Koehn, Jennie E. Daly, and more recently A. D. Daly have produced a small but regular output of agricultural gypsum.

Still another producer active during the third period was the Acme Cement and Plaster Company. In 1909 this company had a calcining plant in Los Angeles in which crude gypsum from Arizona was treated. The property of the Fire Pulp Plaster Company was acquired in 1910, but there was no production. They became a California producer in 1916 with the acquisition and development of the deposit on China Ranch, Inyo County. The gypsum bed was mined with open stopes opened from tunnels. For a time mining was carried on at the rate of nearly a thousand tons a month, but the mine was permanently closed on October 31, 1917.

The fourth period began with the appearance of the United States Gypsum Company among the California producers and ended about 1940 when gypsite production became important.

Perhaps as early as 1910 the United States Gypsum Company was studying California gypsum deposits. The Midland deposit was selected and a four-year development program was begun in 1916. As stated above they bought the Amboy deposit and plant late in 1919. The United States Gypsum Company may not have operated the Amboy calcining plant, for most of the output at this time was used by the portland cement industry.

The completion of the Santa Fe Railroad's Ripley branch in 1922 made it possible to mine gypsum economically from the Midland deposits. The last year for which production from Amboy was recorded was 1924. A crushing and grinding plant was in operation at Midland in 1925, the output from which was largely portland cement retarder. A calcining plant of 300 tons daily capacity was put into operation in August 1928. By 1944 the capacity of the calcining plant had been increased to 800 tons per day, and a wall-board machine was in operation also.

The Fish Creek Mountains deposits likewise were known at an early date, but their large scale exploitation had to await the development of cheap transportation. The San Diego and Arizona Eastern railroad, completed in 1920, passed 25 miles south of the gypsum deposits, and soon after that the Imperial Gypsum and Oil Corporation acquired large gypsum claims in the Fish Creek Mountains. Development, which included the construction of a narrow gage railroad from the San Diego and Arizone Eastern to the deposit, was completed in 1922; and the first shipments of crude gypsum were made in October of that year. The opening of the Fish Creek Mountains deposit resulted in an increase of nearly 100 percent in the total gypsum production.

[61] Hess, F. L., Gypsum deposits near Cane Springs, Kern County, California: U. S. Geol. Survey Bull. 430, p. 417, 1910.

About the same time the California Gypsum Corporation staked a group of claims 2 miles south of the Imperial Gypsum and Oil Company's holdings. No development was done, and the claims have lapsed.

Late in 1924 the Pacific Portland Cement Company bought the Fish Creek Mountains operation and built a calcining plant of 300 tons daily capacity at the junction of the narrow gage railroad and the main line. The plant and the dwellings of the company employees was named Plaster City. For about ten years the output of the Plaster City plant nearly equaled that from Midland. After that the Plaster City production not only fell sharply compared to the total but declined absolutely as well. The Pacific Portland Cement Company began to withdraw from the gypsum business after World War II. The Plaster City plant was sold to the United States Gypsum Company in July 1945. Gypsum properties in Nevada were disposed of about the same time and a wallboard plant in Redwood City in 1949.

In the fifth period the United States Gypsum Company remained the dominant producer. To complete the story of the Fish Creek Mountains, the United States Gypsum Company immediately undertook a program of modernization and expansion. Since its completion a major proportion of California's gypsum production has passed through Plaster City, although the Midland operation is still producing.

The fifth period features the large scale use of agricultural gypsum. A consumption of 3,618 tons in 1933 rose to 490,268 tons in 1947. An estimated five-sixths of the 1947 total was gypsite mined in the San Joaquin Valley. The gypsite industry is characterized by a large number of small operations, most of whom have had but a short life. The Bureau of Chemistry has had almost continuous difficulty with them over failure to tag shipments properly and from failure to meet guarantees.[62] There are, however, a few large operators whose output over a period of several years compares with that of the largest producers of high grade rock gypsum.

Most of the gypsite has come from near Lost Hills. No gypsite was mined there until 1930 when one company was registered. The H.M. Holloway Company's first production came in 1934. Most of the other gypsite deposits operated during the fifth period were discovered and worked on a small scale prior to 1920. They include deposits at McKittrick, Belridge, Tumey Gulch, and Panoche Hills.

Two other significant events occurred in the fifth period. In 1938 production of synthetic gypsum was begun by the Westvaco Chemical Division, Food Machinery and Chemical Corporation at Newark. This gypsum, a byproduct of the manufacture of magnesia, has found a ready market as cement retarder and for agricultural use.

In 1944 Henry Kaiser entered the California gypsum industry with the purchase of the San Marcos Island gypsum deposit and the Long Beach calcining plant of the Standard Gypsum Company. A second calcining plant, at Redwood City, was acquired in 1949 from the Pacific Portland Cement Company. Very considerable quantities of gypsum are brought by ship to these plants.

Mining Methods

Gypsum is a low priced commodity, the average value of which at the mine is reported to be about $2.45 a ton. Probably mining costs are $1.50

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[62] Scott, F. T., Unpublished paper presented at the California Fertilizer Convention, November 7-9, 1949.

a ton or less; and in order to achieve this, large uniform deposits are mined by highly mechanized methods. Complete recovery is rarely feasible.

Blasting is not required for mining gypsite. The use of modern earth-moving equipment is an important factor in making the working of gypsite deposits profitable. Most of the mines use carryall scrapers of up to 4-cubic yards capacity that dump into trucks by means of elevated loading ramps. Dragline scrapers have been tried, and at one deposit a Haiss creeper-model loader is used. Stripping is done in advance of mining with the same type of equipment. The maximum ratio of overburden to gypsite is 1 to 1. Exploration work consists of bulldozer trenches, but hand and power earth augers are occasionally used.

Because of the irregularity of most gypsite deposits, care must be taken to avoid mining worthless material and loading some trucks with waste. If the scraper is set to remove a thin layer at a time the material loaded is fine enough to use without further treatment. In a few cases, however, grinders or screens have been installed.

Rock gypsum must be drilled and blasted. Gypsum, with a hardness of 2, is readily penetrated by both churn drills and hammer drills. With wagon drills from 200 to 250 feet per drill shift in gypsum is realized. Bit wear is small. Auger drills have some application but are not used in California. At Arden, Nevada, auger drills with detachable tungsten carbide bits replaced jackhammers in underground mining, and a marked increase in drilling rate was reported.[63]

Gypsum is more difficult to blast than the harder but more brittle rocks encountered in most mining because it tends to absorb the shock without shattering. A comparatively slow dynamite is often used. No data on consumption of explosive for churn drill hole blasting is available, but for small open pit faces explosive consumption ranges from 0.3 to 0.65 pounds per ton of gypsum broken. For underground mining much larger quantities of explosive are required.

Underground openings in gypsum require little support and remain open for many years. Wall rocks have a wide range in properties. The Tertiary clay shales do not stand unsupported. Limestones and quartzites associated with the pre-Tertiary deposits are strong and require no support. Some of the quartzite is, however, an exceedingly hard and tough rock that is most difficult to drill and blast.

Rock gypsum deposits must be explored thoroughly before mining is attempted. It is to be noted that even in the desert both gypsum and valueless gypsiferous rock are covered by similar gypsiferous outcrops. Trenches and prospect pits may be used to explore outcrops, and prospect shafts have some application. At the Quatal Canyon deposit a number of prospect shafts about 3 feet square and perhaps 40 feet deep were sunk through the hanging wall shale to the underlying gypsum.

Diamond drilling is customarily used to explore a deposit at depth. AX bits, producing a core 1⅛ inches in diameter, are often used, and core recovery is usually close to 100 percent.

A majority of gypsum mines in California are open cut operations. The maximum overburden to gypsum ratio is about 1½ to 1. For large deposits regular benches are maintained by blasting a row of churn drill holes

[63] Nordberg, Bror, Manufacture of gypsum plaster and wallboard: Rock Products, vol. 53, no. 1, p. 140, January 1950.

parallel to the face. Smaller deposits are drilled with jackhammers or wagon drills; and smaller, less regular benches are developed. Flat-lying deposits covered with much over-burden and steeply dipping deposits are mined by underground methods. Room and pillar mining is used extensively in the eastern part of the United States and has been used in California both at Midland and at China Ranch. Less often shrinkage stoping is applicable. When hammer drills are used they are run dry because the cuttings mixed with water would cause the drill to bind. The dust from dry drilling, although unpleasant, is not harmful. Gypsum dust is among the least harmful of all dusts, and it has even been considered as a cure for tuberculosis.[64] The replies to questionnaires sent to members of the gypsum industry in a survey conducted in 1924 indicate that the number of cases of tuberculosis among gypsum works is unusually low.[65] In California, however, the dust concentration in gypsum mines and plants is limited by regulations of the State Division of Industrial Safety to 50 million particles per cubic foot. This compares with a limit of 20 million particles per cubic foot for siliceous dust.

Beneficiation

The only beneficiation commonly practiced on gypsum is sorting. Recently, however, a washing plant has been installed in Nova Scotia to clean crude gypsum before loading it on ships for transport to plants on the east coast of the United States.[66] Sorting with power shovels is commonly carried out in open pits during loading. In the California deposits gypsum differs from anhydrite or other waste enough so that it may be easily identified visually. More rarely hand sorting from belts has been employed. In the Utah Construction Company's mill at Inca Siding provision was made for hand picking of waste from the belt that fed the first grinder, but this station was manned only when labor was plentiful. One gypsite producer installed a screen to remove stones from the gypsite.

Experimental work on the beneficiation of gypsum has, however, been carried out. Some interesting experiments have been made by the Idaho Bureau of Mines and Geology,[67] although it cannot be assumed that the results would be duplicated with all gypsum. The material used was white gypsum that contained bands and nodules of gray siliceous limestone but no clay. It had the following mineral composition:

	Percent
Gypsum	83.7
Anhydrite	4.8
Calcite	2.1
Insoluble	6.0
R_2O_3	1.0
Others	2.4

[64] Forbes, J. J., Davenport, S. J., and Morgis, G. G., Review of literature on dusts: U. S. Bur. Mines Bull. 478, pp. 238-242, 1950.
[65] Rock Products, Experience of gypsum products manufacturers: Rock Products, vol. 27, no. 13, pp. 31-33, June 29, 1924.
[66] Rock Products, Plant operations geared for lowered unit cost: Rock Products, vol. 53, no. 12, p. 96, December 1950.
[67] Prater, L. S., Beneficiation tests on gypsum rock from Washington County, Idaho: Idaho Bureau of Mines and Geology, Pamphlet 77, 6 pp., 1947.

In evaluating the tests the percent of acid insoluble in the various products was considered to be the most reliable indication of the results. Screening tests on material crushed to minus $\frac{1}{4}$ inch showed that the optimum separation was at 28 mesh. In the minus 28-mesh portion, which amounted to about 70 percent of the feed, acid insoluble was reduced from about 6 percent to between 3 and 3.5 percent. When the plus 28-mesh portion was reground in a laboratory pebble mill selective grinding did not take place, and the new minus 28-mesh material was but slightly lower in acid insoluble than the plus 28-mesh pebble mill feed. Tumbling with no grinding medium was tried on minus 1-inch feed, but it resulted in a comparatively small amount of new minus 28-mesh material in which there was no appreciable reduction in the percent of acid insoluble.

Two flotation tests were carried out. With soap flotation a concentrate was made that amounted to 77.4 percent of the heads by weight, and the acid insoluble was reduced from 3.6 percent to 1.2 percent. With amine flotation there was no improvement.

These tests show that by both crushing and screening and by soap flotation the quality of impure gypsum can be substantially improved. In both cases, however, the recovery is so low that for an economical operation a market would have to be found for the rejected material.

The selective flotation of sulfates is more difficult than the flotation of sulfide ores. Not only has there been little occasion to attempt to apply it to such a low cost material as gypsum, but there are technical problems as well. The flotative properties of gypsum have, however, been investigated;[68] and the results are summarized below. The flotation of gypsum in the presence of other minerals was not studied.

Gypsum is readily floated with the soaps sodium oleate and sodium palmitate, and flotation is improved by the addition of a frother such as terpineol, n-amyl alcohol, or n-heptyl alcohol. Gypsum is also floated with the hard-water soap substitutes sodium oleyl sulfate and sodium lauryl sulfate, and with these also a frother improves flotation. The fatty acids are not efficient collectors. With xanthates or xanthates and metal salts there is no flotation.

Using sodium oleate as a collector and terpineol as a frother the effects of other reagents were studied. The flotation of gypsum under these conditions is very sensitive to changes of pH and is most efficient under slightly alkaline conditions. Flotation does not occur when either hydrochloric acid or sulfuric acid reduces the pH to 5.9. Additions of sodium carbonate and calcium hydroxide sharply reduce flotation, while increasing the quantity of sodium hydroxide first decreases flotation and then increases it.

With many nonmetallic minerals, metal salts are added as conditioners to improve flotation. With gypsum, however, metal salts either have little effect or decrease flotation. Colloidal reagents are often used to depress an undesirable mineral. With gypsum, gelatin and tannic acid are efficient depressants; but sodium silicate is not.

[68] Keck, W. E., and Jasberg, Paul, A study of the flotative properties of gypsum: Am. Inst. Min. Met. Eng. Trans. vol. 129, pp. 218-234, 1938.

PROCESSING

For the United States as a whole over 80 percent of the gypsum consumed is in the form of calcined gypsum products. The typical operator prepares the crude gypsum for calcining by crushing and fine grinding. The comparatively small quantities of uncalcined gypsum used for portland cement retarder, as an agricultural mineral, or for fillers and diluents are withdrawn from the appropriate place in the flow sheets of plants that primarily are preparing gypsum for calcining. In California a large proportion of the total gypsum consumption is uncalcined gypsum for agricultural purposes. Because an estimated five-sixths of this agricultural gypsum is gypsite, the processing of rock gypsum in California closely reflects the national practice. Nevertheless California has, or recently has had, operations that prepare rock gypsum for portland cement retarder or for agricultural purposes only.

Little of the equipment used for processing gypsum is unique with the gypsum industry. Crude rock from quarry or mine is reduced with jaw crushers or gyratories, usually in circuit with screens and grizzlies. Hammer mills are sometimes used as primary crushers, but they are more widely used as secondary crushers and primary grinders. Roll crushers are used in some installations. Rotary crushers, formerly popular, are seldom seen today. Gypsum is ground dry. Some gypsum is naturally dry enough so that it can be ground without treatment, but often the crushed gypsum is dried before grinding. The final grinding is commonly done with Raymond roller mills. At a few installations drying and grinding are done simultaneously with Raymond kiln mills.

Agricultural Gypsum [69]

Nearly half the gypsum produced in California is used as agricultural gypsum. In recent years approximately three quarters of the agricultural gypsum has been gypsite containing about 70 percent gypsum, and the remainder has been higher grade material with a gypsum content of 90 percent or more.

Gypsum has been used as an agricultural mineral for many years, and farmers sometimes still call it by its old name "land plaster." Benjamin Franklin encouraged its use by applying it on hillside pasture in the shape of letters so passers-by could read his message written in ridges of higher and greener grass, "This land has been plastered."

California agriculture used only a few thousand tons of gypsum annually until about ten years ago when the tonnage began to increase rapidly. During each of the past 5 years, approximately 400,000 tons of agricultural gypsum have been used in this state, representing an annual outlay of approximately $2,000,000 for material and application. Thus gypsum has become the most important agricultural mineral in California, from the standpoint of tonnage and cost. The Bureau of Chemistry has devoted increased attention to the labeling and claims made for it to assure compliance with requirements of law for protection of purchasers.

The State Department of Agriculture, Bureau of Chemistry, administers portions of the Agricultural Code pertaining to the labeling and

[69] The section on agricultural gypsum is essentially a direct quotation from Rollins, R. Z., Agricultural gypsum, in Minerals useful to California agriculture: Calif. Div. Mines Bull. 155, pp. 105-116. Certain parts of Mr. Rollins' article that are treated elsewhere in this study have been condensed and rearranged.

sale of fertilizing materials and pest control materials. The Bureau is primarily a law enforcement agency. It does not provide recommendations with regard to agricultural practices nor conduct investigations and field tests other than those incidental to its regulatory duties. Agricultural research and agricultural advisory services are provided by the University of California Agricultural Experiment Station, with headquarters at Berkeley, California.

Combined Sulphur Equivalent. Although agricultural gypsum is used for various reasons by different farmers, its value is commonly attributed to its combined sulphur content. The table below affords a convenient comparison of percentages on this basis.

Combined sulphur equivalent.

Gypsum percent	Combined sulphur		Gypsum percent	Combined sulphur	
	Percent	Pounds per ton		Percent	Pounds per ton
100	18.62	372	65	12.10	242
95	17.69	354	60	11.17	223
90	16.76	335	55	10.24	205
85	15.83	317	50	9.31	186
80	14.90	298	45	8.38	168
75	13.96	279	40	7.45	149
70	13.03	261			

Impurities. The impurities in San Joaquin Valley gypsite deposits are mainly silica and other insoluble materials of no agricultural significance. Most of these materials contain a small amount of calcium carbonate, seldom exceeding 10 percent. A typical analysis is:

	Percent
SO_3	33.70
CaO	24.36
SiO_2 and insoluble	18.52
Combined water	15.53
Free water	2.88
Iron and aluminium oxides	1.86
CO_2	1.07
MgO	0.46
Not determined	1.62

Injurious amounts of boron, sodium chloride, or sodium carbonate have not been found, although it is reported that some deposits of gypsum are near deposits of boron minerals.

Mineral deposits contain traces of many elements, some present in small amounts which can be determined chemically and some in traces which can be detected only spectroscopically. Occasionally a registrant of agricultural gypsum obtains a "complete analysis" of his material and proposes to present all the findings on the label as his guarantee. In general this is not acceptable because it may be misunderstood by the average user and be a source of misrepresentation. Claim for the presence of SiO_2, Al_2O_3, Fe_2O_3, and for traces of such elements as titanium, tungsten, vanadium, nickel, and chromium, may be understood as positive claims for their agricultural value. Their presence may be used erroneously to sug-

gest a superiority of a crude gypsum over other gypsums for which such claims are not made.

Some confusion is caused by use of the term *gypsum* to mean both the pure chemical compound $CaSO_4 \cdot 2H_2O$ and the comparatively low grade *gypsite* commonly used for agricultural purposes. Gypsite is a variable mixture of gypsum and impurities, and low grade products may contain only a small percentage of actual gypsum.

Some anhydrite ($CaSO_4$) is sold as an agricultural mineral in California, but most of the material sold here is either *gypsum* containing essentially gypsum 100 percent, or *gypsite* containing gypsum 50 percent to 70 percent. All three forms appear to be of equivalent agricultural value on the soil when compared on an equivalent basis. For example, either 79 pounds of anhydrite or 143 pounds of gypsite containing 70 percent gypsum, would be equivalent to 100 pounds of pure gypsum.

The term *calcium sulphate* is loosely used to designate both the hydrated form, $CaSO_4 \cdot 2H_2O$, and the anhydrous form, $CaSO_4$, and the ambiguous term should be avoided unless used in a context where its meaning is clear. Section 1025 (e) of the Agricultural Code requires the analysis of gypsum to be stated on the tag in terms of ''the percentage of calcium sulphate therein.'' This phrase is interpreted to mean the percentage of gypsum, $CaSO_4 \cdot 2H_2O$, inasmuch as this is the actual ingredient in most such agricultural minerals.

Because 100 pounds of anhydrite may combine with 26.5 pounds of water to form 126.5 pounds of gypsum, pure anhydrite is sometimes said to have a gypsum equivalent of 126.5 percent.

Gypsum is defined by law as an agricultural mineral. It is not a *fertilizer* and it should not be referred to as such. In the terminology of the law, which is familiar to farmers in the state, the term *fertilizer,* or more properly *commercial fertilizer,* refers to materials containing 5 percent or more of nitrogen, available phosphoric acid, or water-soluble potash, collectively or singly. Commercial fertilizers and agricultural minerals may serve different purposes and the two should not be confused. Gypsum does not contain any nitrogen, phosphoric acid, or potash. A reference to gypsum or any other agricultural mineral as a *fertilizer* may be a form of misrepresentation and in violation of law. Similarly the term *plant food* is so commonly used to mean the three primary ingredients in commercial fertilizers, that generally it should not be used with reference to gypsum. The term *fertilizing materials* is properly used to refer collectively to commercial fertilizers, agricultural minerals, manures, auxiliary plant chemicals and soil amendments.

Users have sometimes been misled by the ambiguous statements that gypsum contains SULPHUR or that it contains lime. To the average user, sulphur means elemental sulphur and *lime* means quicklime (CaO) or slaked lime ($Ca(OH)_2$) and to some it means calcium carbonate ($CaCO_3$). Gypsum does contain some chemically combined sulphur, but it does not contain elemental sulphur; neither does pure gypsum contain any of these calcium compounds. The problem is further complicated by the fact that gypsum, elemental sulphur, and three *liming materials* (quicklime, hydrated lime, and limestone, which is calcium carbonate) have distinctly different agricultural uses, and use of one when another is more appropriate may be ineffective or detrimental. Gypsum is not a liming material. Elemental sulphur tends to make soils acid; liming

materials tend to make soils alkaline; gypsum has no immediate effect on acidity or total alkalinity of the soil, but its use may influence the form of the alkalinity. The differentiation between these materials by users may be somewhat confused by the fact that some mixtures of the different chemicals have been sold in California. For example, mixtures of calcium carbonate and gypsum have been marketed here, and a natural mixture of elemental sulphur and gypsum has been brought into the state for agricultural use.

Source. Much of the agricultural gypsum used in California comes from the gypsite deposits found in the western foothills of the San Joaquin Valley. Agricultural gypsum is also prepared from rock gypsum by fine grinding. Most of the rock gypsum is ground by producers who are primarily engaged in the plaster business. Some synthetic gypsum is used for agricultural purposes. It is of interest that approximately half of normal superphosphate is anhydrite, and many tons of this are used as a commercial fertilizer in California.

Agricultural Use. Most of the agricultural gypsum sold in California is used in San Joaquin Valley within trucking distance of local deposits, although a portion of the tonnage is used in other parts of the state. It is applied to improve soil texture, increase permeability to water, alleviate severe clod and crust formation, render the soil easier to work, and to aid in the reclamation of alkali soils. Gypsum reacts with sodium carbonate, commonly called black alkali, to form sodium sulphate, commonly called white alkali, and calcium carbonate, which is the same as limestone. Sodium sulphate is much less injurious to plant life than sodium carbonate, so the conversion is of distinct advantage. Soils alkaline with sodium carbonate are sticky when wet, and set to a hard cake when dry. Addition of gypsum aids in flocculating the mass and tends to make the soil loose and friable.

Gypsum is applied to soils where many of the diversified crops are grown as in the San Joaquin Valley, and particularly on those for potatoes in Kern County where most growers use gypsum primarily to improve penetration by water during irrigation. Gypsum is also used on sulphur-deficient soils to supply this element to alfalfa and leguminous cover crops. The use of gypsum in California is correlated with soil type rather than with any specific crops, but the other crops most commonly grown in the area of greatest use include citrus and deciduous orchards, vineyards, cotton, and vegetables. No accurate data are available with regard to the tonnage of gypsum used on specific crops or in specific counties.

Gypsum is not suitable for reducing acidity of soils. However, most agricultural soils in California are commonly somewhat alkaline, and acid soils are a problem in only a few places in the state. Gypsum may be largely wasted if applied to acid soils or to light loam or sandy soils, unless an actual deficiency of soil-sulphur or soil-calcium is involved.

Application. The rate of application of gypsum varies greatly depending upon the crop involved, the degree of correction required by the soil, and the purpose for which it is used. In general, applications range from less than 1 ton to as high as 20 tons per acre. Some soils are given but a single application and some are given regular annual applications

for several consecutive years. It is possible that a soil might be more or less permanently corrected by a program of annual applications over a sufficient period, but this seems not to have been demonstrated.

Gypsum is usually spread on the soil and turned under by shallow cultivation. It is sometimes applied to soils by means of end-gate spreaders attached to the same trucks that are used to haul it from the mines to the fields, and several special types of equipment have been developed in the San Joaquin Valley to minimize labor in spreading this agricultural mineral.

Some application of gypsum has been made by dissolving it in irrigation water. However, only about a quarter of an ounce of gypsum can be dissolved in a gallon of water under most favorable circumstances, which is equivalent to about 2½ tons in one acre-foot of water. This low solubility and the difficulties involved in adequately mixing the gypsum with the incoming water present a problem. Mechanical arrangements have been developed for metering gypsum into irrigation water at the rate of several hundred pounds per acre. This method is particularly useful when gypsum is being added to correct an unfavorable sodium-calcium ratio in the irrigation water.

If gypsite containing gypsum 70 percent were used in such a manner, the sludge comprised of the 30 percent of the more insoluble impurities might clog the irrigation system. This method of application would seem satisfactorily possible only when high grade gypsum is used, and only when low rates of application are desired.

Much of the gypsum is applied during the winter months when trucking facilities are readily available, but some is applied throughout the year as may be seen from the quarterly tonnage statistics published by the State Bureau of Chemistry.

Soil Conservation Program. In accordance with the soil conservation program, the Federal Production and Marketing Administration makes certain payments to farmers who apply soil sulphur or its equivalent as combined sulphur in the form of gypsum to an existing stand of, or in connection with, a full new seeding of perennial or biennial legumes, perennial grasses, green manure crops in orchards, permanent pastures seeded alone or with a nurse crop, and winter legumes; or where the County Committee determines such application is necessary to correct alkali soil conditions.

Information is not available to show what percentage of the gypsum used in California was eligible for payments under the P. M. A. program in 1949, but partial data indicate that about half the gypsum used in San Joaquin Valley in 1947 was used in an eligible manner. Payment is made on a basis of the amount of sulphur equivalent, and it is reported that in 1947 payment was made on 210,847 tons of gypsum (18 percent combined sulphur) applied to 294,690 acres on 4,452 farms. In 1946 payment was made on 23,751 tons of "available sulphur" applied on 5,250 farms, on 219,630 acres.

Statistics of Sales. The law requires each registrant of agricultural minerals to submit a quarterly statement of sales and pay a tonnage license tax of 10¢ per ton. These reports are regularly audited. The private business of individual firms is safeguarded by publishing figures

only for those types of agricultural minerals reported by three or more firms, but gypsum has always been reported by a large number of firms. The tonnage of agricultural gypsum sold in California during the last 25 years is shown in the table below.

In the same 25-year interval, the total tonnage of all agricultural minerals sold in California increased from 44,241 to 422,484 and the tonnage of commercial fertilizers increased from 66,274 to 511,460. In 1924, gypsum represented approximately 10 percent of the total tonnage of agricultural minerals. In 1949, it represented approximately 80 percent.

The tonnage of gypsum handled in 1948 may be better visualized by considering that it was equivalent to about 40,000 truckloads of 10 tons each, or more than 100 truckloads per day every day in the year. Assuming a probably average haul of 50 miles, this represents a total haul of about 2,000,000 miles.

Tons of agricultural gypsum sold in California.

Year	Tons sold	Year	Tons sold
1924	4,085	1937	24,218
1925	6,504	1938	17,580
1926	11,049	1939	42,878
1927	10,185	1940	77,195
1928	14,120	1941	122,304
1929	15,269	1942	185,856
1930	11,449	1943	300,980
1931	5,583	1944	395,174
1932	4,410	1945	367,108
1933	3,618	1946	414,286
1934	7,914	1947	490,268
1935	16,787	1948	394,979
1936	17,328	1949	338,340

The tonnages shown represent crude gypsum as sold. The available data do not permit an accurate calculation of the actual gypsum equivalent for each year, but in recent years approximately three-quarters of the tonnage has been San Joaquin gypsite containing gypsum about 70 percent and one-quarter has been higher grade material containing 90 percent or more.

Requirements of Law. Gypsum is classified by the Fertilizing Materials Article of the Agricultural Code as an "Agricultural Mineral." It must be sold in accordance with the provisions of this law, which requires among other things that:

(1) Gypsum must be from the supply of a person or firm who has obtained from the Bureau of Chemistry a certificate of registration for agricultural minerals, and who has registered each composition to be sold.

(2) Gypsum can be sold only by the holder of a fertilizer salesman's license. There are several exceptions: a registrant may sell his own registered products without a fertilizer salesman's license and such a license is not required for a dealer to sell gypsum in a registrant's package from a fixed place of business.

(3) Each lot or bag of gypsum must bear a tag stating the percentage of gypsum ($CaSO_4 \cdot 2H_2O$), and the name and address of the registered producer. If the material is sold in a loose lot, a tag bearing the required

information should be firmly attached to a stake driven into the pile so as to be plainly visible while in transit and upon delivery to the user.

(4) A tonnage license tax of 10¢ for every ton sold must be paid quarterly by the registered producer.

It is a misdemeanor to make any misrepresentation in connection with the sale of any fertilizing material. For example, it is not acceptable to claim that gypsum ''contains sulphur'' or that it ''contains plant foods'' or that it is a ''fertilizer'' if such claims are made in a manner that may lead the purchaser to believe the material contains elemental sulphur, nitrogen, phosphoric acid, or potash.

Administration of Law. The Bureau of Chemistry administers the Fertilizing Materials Article of the Agricultural Code as well as certain portions of the Code pertaining to other agricultural chemicals. The main office and laboratory of the Bureau are in Sacramento. Branch offices are in Los Angeles, San Francisco, and Visalia. Inspectors travel throughout the state and regularly draw official samples of gypsum, as well as other agricultural chemicals offered for sale in California. The official samples are analyzed in the laboratory and the results of analyses are sent to the user of the particular lot sampled, to any dealer who may be concerned with the particular lot, and to the registered producer. There is no charge for this service. If analysis shows that there is a deficiency of economic significance in the lot sampled, the registrant is requested to produce evidence that proper adjustment has been made to the purchaser.

In order to permit reasonable leeway for unavoidable variations in marketing, the law provides that a lot of gypsum is not to be considered deficient unless the percentage is low by more than 5 percent of the guarantee. For example, if a lot is guaranteed to contain gypsum 70 percent and contains less than 66.5 percent, it is deficient and to sell it or to offer it for sale is a violation of law.

All claims made with regard to gypsum and other fertilizing materials are subject to jurisdiction of the law. The Bureau examines advertisements in periodicals, advertising distributed in the form of cards, leaflets, bulletins, or letters, and also considers radio advertising, salesmen's verbal claims, and all other claims made directly or indirectly in connection with the sale of these agricultural chemicals. Prompt action is taken against misrepresentation in any form in order that farmers in California may purchase agricultural chemicals with confidence and satisfaction.

Criminal complaints are filed when necessary to secure compliance with law. Repeated violations by firms dealing in gypsum have resulted in cancellation of certificates of registration, without which any sale is a misdemeanor. Constant vigilance and thorough enforcement of law not only discourages violations and secures some compensation of purchasers for economic cheats in the materials they buy but, by its presence alone, a well-administered law serves to minimize attempts of fraud and misrepresentation.

Sampling. Much of the gypsum used in California is hauled loose in truckload lots directly from the mine to the field on which it is to be used, so it remains in the channels of trade and subject to inspection and sampling for a shorter time than other agricultural chemicals. Inspectors must arrange their sampling activities according to availability of the mate-

rial for inspection. Samples are usually drawn from truckloads en route and occasionally from lots delivered and left intact at farms. Some gypsum is sold in bags, and this material is subject to inspection and sampling wherever found in hands of dealers or purchasers.

Section 1037 of the Agricultural Code provides that if the fertilizing material is packaged in containers of less than 10 pounds, one package of the material may be taken as a sample to represent the lot of which it is a part, but gypsum is seldom sold in small packages.

When gypsum is packaged in containers of 10 pounds or more, each official sample consists of at least 1 pound of material taken in the following manner: A sampler is used to remove a core diagonally from end to end of the bag. Cores are taken from all bags if 20 or fewer are present. If 21 to 200 bags are present, 20 cores are taken from as many bags. If more than 200 bags are present, cores are taken from 20 bags plus 1 bag for each additional ton in excess of 10 tons. The portions are thoroughly mixed on a clean rubber sheet, oil cloth, or paper, and reduced by quartering to the quantity of sample required. Opposite quarters are placed in one sample container and the remainder in another for a duplicate sample.

When gypsum is sold in a loose lot by truckload or carload, the load constitutes one package. An official sample is taken in the following manner: The outer surface is scraped aside before inserting sampler, because the load may have been wet with a hose to reduce dust or the wind may have blown the fine material from the surface, and at least 20 approximately equal cores are taken from fairly evenly distributed parts of the quantity. If more than 10 tons are contained in a lot, two cores are taken for each additional ton. Portions are taken with a trowel when the material contains large lumps or when for other reason it is not possible to use a sampler. Lumps are broken if necessary and the material is mixed, quartered, and placed in sample containers.

An official sample of a fertilizing material is sealed before removal from premises where it was drawn. The seal bears the date; name of product as given on the label, if any; signature of person acknowledging the sample; inspector's initials and sample number. The duplicate portion is sealed and left with the party whose stock was sampled or left on the premises where it was drawn.

A total of 180 official samples of gypsum were drawn and analyzed during 1948; these represented a total of 10,256 tons. Since 394,979 tons of gypsum were sold in California during 1948, it can be seen that 2.6 percent of the total tonnage was specifically examined by the Bureau of Chemistry. For every sample of gypsum drawn and analyzed during the year, approximately 2,194 tons were sold. By way of comparison, one sample of commercial fertilizer was drawn for every 262 tons sold. In general, commercial fertilizers are more expensive and more important to farmers than agricultural minerals, and the purpose of the law is served most effectively and economically by sampling the more important materials more intensively.

Analyses for Users. The law provides that a person who is actually using or intends to use an agricultural mineral for fertilizing purposes may submit a sample for analysis to determine conformity or nonconformity of the material to the guarantee under which it is sold or is to be sold. The user submits information with regard to the lot of material, a copy of the tag, and the service fee which is $4 for analysis of gypsum.

Users rarely submit samples for analysis because a report issued on such a sample does not have the legal status of a report issued on an official sample drawn directly by the Bureau, and no charge is made for official samples.

Publications. The results of analyses of official samples of commercial fertilizers and agricultural minerals drawn during each calendar year are published annually by the Bureau. These analyses serve not only as a guide in administration of the law, but are an important source of information to users. Farmers can readily compare analyses of different types of materials, and compare the records of different registrants in meeting the guarantees made for their materials. Interested persons familiarize themselves with the law governing sales of gypsum to assure value received for the money they spend when buying their supplies.

Copies of the law, annual reports of this Bureau, lists of registered firms and of registered products, special publications providing analyses of official samples, announcements with regard to special items of interest, and other informative publications of agricultural chemicals are available upon request from the Bureau of Chemistry, 1125 Tenth Street, Sacramento 14, California.

Portland Cement Retarder

The portland cement industry is an important consumer of uncalcined gypsum, and in California 100,000 to 150,000 tons of gypsum a year are used by cement plants. The gypsum, which serves to retard the naturally fast set of portland cement, is added to the clinker before grinding. Specifications limit most cements to 2 percent SO_3, although some cements may contain up to $2\frac{1}{2}$ percent SO_3. These percentages are achieved by the addition of 85 to 100 pounds of gypsum per ton of clinker. Greater quantities reduce the final strength of cement. The function of gypsum in the setting of portland cement is a complex matter that is not completely understood. Bouge has summarized the work of many investigators.[70]

Portland cement plants commonly require that the gypsum contain a minimum of 92 to 93 percent $CaSO_4 \cdot 2H_2O$, although material containing 85 percent gypsum or less has been used. Gypsum of over 90 percent purity is not likely to contain harmful quantities of deleterious substances. Anhydrite, however, cannot be indiscriminately substituted for gypsum on an equivalent SO_3 basis. The use of anhydrite as portland cement retarder is discussed more fully in another section of this report.

Portland cement plants require sized gypsum. Probably a majority are accustomed to using and require "pebble" gypsum which is plus $\frac{3}{8}$ inch and minus $1\frac{1}{2}$ inches. These plants find that fine gypsum is difficult to handle and store, and also that better grinding is accomplished when the gypsum and clinker are approximately the same size. The upper size is usually limited by the capacity of the tube mills that grind the mixture of gypsum and clinker, but some plants have crushers for reducing coarse gypsum to a convenient size. Other plants use fine gypsum and require that the gypsum be finely ground. A few plants that use fine gypsum have grinding equipment and accept either coarse or fine gypsum.

[70] Bouge, R. H., The chemistry of portland cement, pp. 472-487, New York, Reinhold Publishing Corp., 1947.

Calcination of Gypsum

Calcium Sulfate and Its Hydrates

It has been known since ancient times that when gypsum is calcined at a moderate temperature, the resulting material sets or hardens when mixed with water. A thorough study of the system $CaSO_4$-H_2O has been made by Kelley, Southard, and Anderson.[71] Riddell [72] has prepared a summary of this highly technical work to which he has added some data of his own.

Although many forms of calcium sulfate and its hydrates have been postulated, only six forms have been accepted or are reproducible in the laboratory. The dihydrate ($CaSO_4 \cdot 2H_2O$) occurs naturally as gypsum or may prepared in the laboratory by precipitation from solution at room temperature or by allowing calcined gypsum to rehydrate. X-ray studies show that all the natural and synthetic types of gypsum have the same crystal structure and that the water of crystallization cannot be removed without destroying the crystal lattice.

There are two forms of the hemihydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$). The crystal structure of both is such that the water of crystallization can be varied considerably without destroying the crystal structure. The more stable form, alpha $CaSO_4 \cdot \frac{1}{2}H_2O$ may be prepared by crystallization from acid solutions, dehydration of gypsum in water at over 97°C. or dissociation of gypsum in an atmosphere of saturated steam. The less stable beta $CaSO_4 \cdot \frac{1}{2}H_2O$ differs from alpha $CaSO_4 \cdot \frac{1}{2}H_2O$ in energy content and solubility. It slowly changes to the stable form. Beta $CaSO_4 \cdot \frac{1}{2}H_2O$ is prepared by partly dehydrating gypsum in a vacuum at 100° C. or in an atmosphere not saturated with steam.

There are three forms of anhydrous calcium sulfate. Two forms, analogous to the hemihydrates, rehydrate in water and are called soluble anhydrite. The third form, insoluble anhydrite, does not rehydrate at an appreciable rate.

Alpha soluble anhydrite is prepared by dehydrating alpha hemihydrate in a vacuum or at 110° C. in air saturated with water vapor. Beta soluble anhydrite is prepared by dehydrating beta hemihydrate at 100° C. or gypsum at less than 200° C. in an atmosphere not saturated with steam. The soluble anhydrites have great affinity for water and have some application as drying agents. It is difficult to remove the last traces of the water of crystallization without destroying the crystal structure.

Insoluble anhydrite is prepared by crystallization from salt solutions at 100° C. or by heating any of the other forms of calcium sulfate for one hour at a temperature up to 900° C., the dissociation temperature of calcium sulfate. Material formed in either of these ways is identical with natural anhydrite.

Setting of Gypsum Plaster.[73] Two theories have been advanced to explain the setting of gypsum plaster, the crystallization theory and the colloid hypothesis. The crystallization theory supposed that when water is added, the hemihydrate goes into solution. Because $CaSO_4 \cdot 2H_2O$ is

[71] Kelley, K. K., Southard, J. C., and Anderson, C. T., Thermodynamic properties of gypsum and its dehydration products: U. S. Bur. Mines Tech. Paper 625, 73 pp., 1941.

[72] Riddell, W. C., Physical properties of calcined gypsum: Rock Products, vol. 53, no. 5, pp. 68-71, 102, May 1950.

[73] Bouge, R. H., The chemistry of portland cement, pp. 352-367, New York, Reinhold Publishing Corp., 1947.

less soluble than the hemihydrate, the solution is supersaturated with respect to $CaSO_4 \cdot 2H_2O$, and $CaSO_4 \cdot 2H_2O$ precipitates.

According to the colloid hypothesis, when water is added to the plaster a gel is first formed. The gel slowly takes up water and changes to needle-shaped crystals of $CaSO_4 \cdot 2H_2O$.

Commercial Calcination

In the laboratory gypsum may be calcined to the hemihydrate at temperatures as low as 130° F. Because the time to reach equilibrium at such low temperatures amounts to many days, commercial calcination is carried out at temperatures between 300° F. and 400° F.

Gypsum is commonly calcined in batch machines called kettles whose capacity ranges from 10 to 20 tons of uncalcined gypsum. The modern kettle is a steel cylindrical shell 6 to 14 feet deep and 8 to 15 feet in diameter. The bottom, which is convex upward, rests directly on the firebox. Rabble arms driven by a vertical shaft are placed close to the bottom to prevent sticking of the charge to the hot bottom. Furnace gases from the firebox pass through an annular space between the kettle shell and the outside brickwork and are directed by means of baffles through horizontal flues, usually four, that pass through the kettle. The kettle is loaded from the top and discharged through a spout in the bottom. Steam produced during calcination is vented through a dust separator to the atmosphere.

The kettle is loaded with gypsum ground to 70 to 90 percent minus 100 mesh. Present practice is to fill the kettle as rapidly as possible; the average time is about 15 minutes. Although heat is applied at a constant rate, the temperature of the charge rises rapidly to between 250° and 255° F. and then remains nearly constant for much of the period of calcination. During this period of constant temperature, the rapid evolution of the water of crystallization as steam causes a vigorous boiling and rising of the charge. As the composition of the material approaches $CaSO_4 \cdot \frac{1}{2}H_2O$ the boiling dies down, the charge settles in the kettle, and the temperature rises again at an increasing rate. At 300° F. the material has a water content somewhat less than that of the hemihydrate. Calcination is ordinarily stopped at about 340° F. by opening the discharge spout and dumping the contents of the kettle into an adjacent chamber called the hotpit. The kettle is then loaded again with raw gypsum and the cycle is repeated. The time of calcination, which depends on the rate of firing, is between 2 and $2\frac{1}{2}$ hours. Material made in this way is called single boil or first settle stucco [74] and is the semi-finished material from which almost all calcined gypsum products are made.

Single boil kettle stucco approaches the composition of the hemihydrate (6.2 percent H_2O), but the water content ranges from the theoretical down to as little as four percent. Measurements made on stucco from different plants show that single boil stucco may contain as much as 10 percent beta soluble anhydrite and that as much as a third of the hemihydrate may be in the beta form.[75] The relative proportions of these dehydration products depend on the character of the raw gypsum,

[74] The term "stucco" is commonly used to designate calcined gypsum that has received no further treatment. Stucco is defined by the American Society for Testing Materials, however, as follows: "A material used in a plastic state, which can be troweled, to form a hard covering for the exterior walls or other exterior surfaces of any building or structure." A.S.T.M. designation: C11-48.

[75] Kelley, K. K., Southard, J. C., and Anderson, C. T., Thermodynamic properties of gypsum and its dehydration products: U. S. Bur. Mines Tech. Paper 625, pp. 63-68, 1941.

the conditions under which calcination was carried out, and the treatment of the stucco after calcination. These proportions in turn influence the properties of the stucco. The setting time of single boil stucco ranges from less than 15 minutes to more than 40 minutes and averages about 30 minutes. The tensile strength is up to about 300 pounds per square inch. Like portland cement the strength of set plaster continues to increase for many hours after the initial set. The compressive strength is about 10 times the tensile strength. For most testing purposes tensile strength rather than compressive strength is measured.

Relations Between the Properties of Stucco. Consistency is a measure of the ability of stucco to absorb water. Normal consistency is defined by the American Society for Testing Materials and is determined with the Vicat needle.

Normal consistency is measured by the weight of mixing water required expressed as a percentage of the dry material.

Usually a plaster of high consistency is more plastic than a plaster of low consistency, but the relation between consistency and plasticity is not proportional. A plaster of high consistency has great bulk when wet and can cover a larger area than a low consistency plaster. When dry, however, it is porous and less strong than a low consistency plaster.

Factors that Influence the Properties of Stucco. Most of the insoluble impurities likely to be found in the raw gypsum accelerate the setting time of the stucco made from it. Deliquescent salts increase the strength. Increased fineness of grind of the feed accelerates the setting time, increases the consistency, and decreases the strength.

The maximum temperature reached during calcination influences the setting time. Stucco with the fastest set is made by calcining at between 320° and 360° F. Maximum temperatures both higher and lower than this produce stucco with a slower set. Increased strength results both from increasing the time of calcination and raising the maximum temperature. Faster calcination produces stucco of higher consistency. If the calcination is carried out so that either raw gypsum or dead burned gypsum gets into the stucco, the set is accelerated.

The effect of leaving the stucco in the hotpit is to allow calcination to continue. The setting time is accelerated, the consistency is lowered, and the strength is increased. Aging is the slow rehydration of the stucco. Consistency is decreased, strength is increased, and the setting time is retarded. Aging is desirable for casting and similar plasters. Artificial aging is accomplished by adding a salt, particularly calcium chloride, to the kettle charge or by spraying a fine mist of water into a mixer of stucco.

Regrinding the stucco increases the consistency. Tube mills are more effective than other grinders for this purpose.

Double Boil Kettle Stucco. Less double boil stucco is made today than formerly. If the single boil stucco is retained in the kettle instead of being dumped at about 340° F. the temperature continues to rise to about 370° F. and then remains nearly constant. A second boiling takes place, and after it subsides and the charge settles for the second time there is a renewed increase in the temperature. The calcination is stopped at about 415° F. because a higher temperature produces a large proportion of dead burned gypsum or insoluble anhydrite.

Double boil stucco is essentially soluble anhydrite. It is a material of low consistency, quick set, and high strength that was formerly used for casting plaster. Most casting plaster is now made, however, by artificially aging single boil stucco.

The Calcination of Gypsite. In the past gypsite has been calcined in kettles in California and elsewhere in the United States.[76] Because of gypsite's wide variation in gypsum content, high moisture content, and sometimes the presence of organic matter, the calcination is difficult. Loading is done slowly in order to prevent the charge from sticking to the bottom of the kettle. After each increment the charge is allowed to reach the boiling stage before the next addition. The calcination time for a 10-ton charge is from 3 to 8 hours.

Gypsite stucco is dark colored and slow setting. It has been used for wall plaster.

Continuous Calcination. A few plants in the United States calcine gypsum in rotary kilns, but there are no rotary calciners in California. A coarse feed from which the fines have been screened is used.

Stucco for some purposes can be prepared by flash calcination. Two California plants use the Raymond Imp kiln mill. Although it is widely used for drying clay and chemicals, the Imp kiln mill has been adapted for calcining at only a few plants.

The Imp kiln mill consists of a hammer mill with an exhaust fan at one end of the shaft. The hot gases from an adjacent furnace enter at the other end. Gypsum crushed to 1 inch or finer is introduced from a hopper with a star feeder into the intake stream. In a conical chamber between the fan and the hammers are the whizzer blades set so as to throw uncalcined lumps back towards the hammers. During the estimated 15 seconds the gypsum stays within the mill, flash calcination and grinding take place simultaneously. The action of the mill can be controlled by adjusting the rate of feed, the temperature of the furnace gases, and the position of the whizzer. The maximum capacity of the Imp kiln mill is 2 to 3 tons of stucco per hour. Larger Imp mills are used as driers, but gypsum has not been economically calcined in them.

The hot, finely ground stucco is removed from the furnace gases and steam with a cyclone separator and cooled in air before being placed in storage bins.

Stucco produced in the Imp kiln mill differs from kettle stucco in a number of its physical properties, including the time of setting and solubility. Solubility tests made by W. C. Riddell[77] show that Imp kiln mill stucco contains a large proportion of the metastable hemihydrate beta $CaSO_4 \cdot \frac{1}{2}H_2O$. The average setting time of 15 minutes contrasts with the 30-minute setting time of kettle stucco which is high in alpha $CaSO_4 \cdot \frac{1}{2}H_2O$. The rapid setting time of stucco produced in the Imp kiln mill is one reason why it may be advantageously used for wallboard.

Finishing the Plaster

Stucco from the calcining kettle is ordinarily left in the hotpit for no longer than about an hour. Continued hotpit storage allows calcination to continue and usually results in inferior plaster. Stucco is a very light,

[76] Turner, A. M., The manufacture of gypsum plaster—Part I: Rock Products, vol. 33, no. 22, pp. 49-51, 1930.
[77] Riddle, W. C., Physical properties of calcined gypsum: Rock Products, vol. 53, no. 5, pp. 70, 71, May 1950.

powdery material that tends to flow like water and leaks readily through small holes. Generally it is handled with screw conveyors.

Stucco is usually reground after its removal from the hotpit, although stucco for certain uses is not reground by all manufacturers. It has been established that grinding with steel balls increases the consistency of the plaster, and stucco for hardwall plaster is usually reground in tube mills. Buhr mills are used when it is not desired to increase the consistency.

The final operation is the addition of materials to regulate the setting time, fiber, aggregate, or sometimes other additives. The additions are made in batch mixers of about 1 ton capacity. The finished plaster is packed in paper bags that hold 100 pounds.

The set of most plasters is modified by the addition of retarders or accelerators. Clay and most organic materials are retarders. Glue, starch, or sugar, are effective; but the material ordinarily used is commercial retarder prepared especially for the plaster industry. Commercial retarder is made from hoof meal, slaughter house tankage, or similar material cooked with lime and caustic. To obtain a setting time of 6 hours, from 3 to 15 pounds of retarder per ton of plaster are required. The effect of commercial retarder depends to a notable degree on the temperature at which the plaster is to be used. Less of it is required in summer than in winter. Other variables affecting the amount of retarder required are the setting time of the stucco from which the plaster is made and the presence of set-influencing impurities in the water and aggregate to be mixed with the plaster. For example, the same plaster mixed with different sand may have vastly different setting times. In one series of tests the setting times ranged from less than 2 hours to 15 hours.[78] Consequently the amount of retarder added depends on where and in what season the plaster is to be used. Although the set can be adjusted at the time of use, it is better practice to use plaster prepared by the manufacturer for the particular locality.

Most metal salts are accelerators. Gypsum, set plaster, dead-burned gypsum, and anhydrite are very effective under certain conditions. An addition of 10 pounds of dry gypsum per ton of plaster reduces the set to 5 minutes or less, but if the gypsum is damp or the plaster is hot, much larger quantities are required. Large additions of gypsum weaken the plaster. Salt is as effective as gypsum and may be added to hot plaster. Potassium sulfate, zinc sulfate, and alum may cause efflorescence on the surface of the set plaster.

Other additives may be a binder such as hair or sisal fiber, an aggregate, or pigments for making colored plaster. Aggregates include sand, wood fiber, vermiculite, and perlite. Usually sand is added to plaster at the place of use, but some sanded plaster is prepared by the manufacturer for use in areas where good plaster sand is scarce.

Anhydrous Plasters

There are a number of low consistency, high strength plasters made by calcining gypsum at a temperature high enough to drive off all the water of hydration. In one group of plasters the gypsum is heated to about 1,000 degrees F., and to the ground calcined product accelerators are added. This group includes Keene's cement, Parian cement, Mack's

[78] McAnally, S. G., Gypsum and gypsum products manufacture—Part VIII: Rock Products, vol. 34, no. 6, p. 58, March 14, 1931.

cement, Martin's cement, and Magand's cement. They differ chiefly in the accelerators used. Another anhydrous plaster is flooring plaster, made by calcining gypsum at a temperature high enough to decompose part of the calcium sulfate. Of all the anhydrous plasters, Keene's cement is the only one that is used in the United States.

Keene's Cement. Keene's cement is a gypsum product that is not made in the calcining kettle. Raw gypsum is converted to insoluble anhydrite by calcination at 600° to 1300° F. in beehive or rotary kilns. The calcined gypsum is then finely ground. Accelerators are added that cause the cement to set in 1 to 4 hours. Dehydrated alum, sodium sulfate, potassium sulfate, and borax are among the accelerators used, and additions of about one percent are made. Keene's cement is harder and stronger than ordinary gypsum plaster. The minimum permissible tensile strength is 400 pounds per square inch.[79]

Gypsum of over 99 percent purity is required because small quantities of impurities either cause discoloration or weaken the cement. Keene's cement is manufactured at only two or three plants in the United States. Most of it is used for finishing plaster.

MARKETING

Gypsum Products

Building Plasters

Most of the gypsum plasters are consumed by the building industry. Gypsum plaster is eminently suited for building use not only because of its strength and permanence but also because of its resistance to fire. In a manner analagous to the melting of ice, the temperature of set plaster cannot rise above 200° to 250° F. until it has been completely calcined. Calcination progresses through a plaster wall at the slow rate of about ¼-inch in 15 minutes. Exhaustive studies have established standards for fire resistance for numerous types of construction. For example, walls having half an inch of plaster have fire resistive ratings of 45 minutes to 1 hour, depending on the kind and amount of aggregate in the plaster and the type of lath.

The use of gypsum in building is covered by rigid specifications. Specifications of the American Society for Testing Materials are concerned with the properties of gypsum plasters and manufactured products, aggregates, and methods of testing. The American Standards Association has established the manner in which gypsum as well as other kinds of building materials are to be used.

Basecoat plasters, of which there are four standard types, consume the greatest quantity of gypsum used for building plaster. Hardwall plaster, called cement plaster in other parts of the country, is the most important basecoat plaster. It is applied directly to all kinds of lath and most other surfaces except monolithic concrete. It is furnished neat which means that it contains retarder but no aggregate. When it is mixed with 3 parts of sand the minimum time of setting is 2 hours, and the minimum tensile strength when mixed with 2 parts of sand is 125 pounds per square inch.[80] Neat hardwall plaster may contain hair or sisal fiber. Although

[79] A.S.T.M. designation: C 61-40.
[80] A.S.T.M. designation: C 28-40.

the fiber does not contribute to the strength of the plaster, it does prevent excessive loss of plaster through the keys of some kinds of lath.

Hardwall plaster is mixed with as much as three parts by weight of sand at the place of use. Greater quantities of sand cause a marked decrease in the strength and hardness of the set plaster and reduces its fire resistance. Vermiculite and perlite may be substituted for sand provided that the particle size conforms to specifications for plaster sand. Two to three cubic feet of vermiculite per 100 pounds of neat plaster are used. Both vermiculite and perlite increase the fire resistance of plaster, but the strength is less than when sand is used. Perlite plaster is stronger than that which contains vermiculite.

The second type of basecoat plaster is sanded gypsum plaster. Intended for the same uses as hardwall plaster, it is mixed with sand at the plaster factory and is available both with or without fiber. Sanded gypsum plaster is used where good plaster is scarce or when it is desired to eliminate the possibility of mixing too much sand or inferior sand with the plaster.

Gypsum wood fiber plaster is the third type. Wood fiber is added at the plant as a substitute for sand or other aggregate. Wood fiber plaster is stronger and harder than hardwall plaster and has somewhat greater resistance to fire.

The fourth type is bond plaster, a material for direct application to concrete surfaces. Hardwall plaster is unsatisfactory because of the difference in thermal expansion between concrete and gypsum and because of the smooth dense surface of concrete, especially monolithic concrete. Bond plaster is especially prepared to overcome these limitations, and it is for use on concrete only.

Finish coat plasters are used for the final $\frac{1}{16}$ inch to $\frac{1}{8}$ inch of the plaster. The most commonly used is lime-gauging or white coat finish, which is composed of three parts by volume of lime putty gauged [81] with one part of gauging plaster. Gauging plaster is a coarsely ground plaster of low consistency and comparatively fast set. Molding plaster, used for gauging lime putty for cornice moldings, resembles gauging plaster except that it is ground to a fineness of 90 percent minus 100 mesh. The setting time is 20 to 40 minutes, and the minimum tensile strength is 200 pounds per square inch.[82] Neat hardwall plaster is unsatisfactory for gauging. Keene's cement may be used neat for finishing, or it may be used for gauging lime putty. Lime-Keene's cement finishes are harder and stronger than lime-gauging finishes. There are also prepared gypsum finishes that require only the addition of water at the place of use. They are harder than finishes containing lime; and unlike the lime finishes, they may be painted as soon as they are dry. The minimum tensile strength is 200 pounds per square inch, and the setting time is 20 to 40 minutes.[83]

Acoustical plaster is a sound-absorbing finishing plaster for use on ceilings or walls in place of the usual finishing coat. It is prepared at the plant and requires only the addition of water at the time of use. Although it is hard and incombustible, acoustical plaster has a cellular structure that absorbs sound.

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[81] Gauging is the mixing of plaster with lime putty in order to acquire the proper setting time and initial strength.
[82] A.S.T.M. designation: C 59-40.
[83] A.S.T.M. designation: C 28-40.

Prefabricated Products

A little more than half of the gypsum consumed by the building industry is in the form of prefabricated products. By far the most important are gypsum wallboard, lath, and sheathing board. Cast shapes of several sizes are available, but they constitute less than 1 percent of the total production of prefabricated gypsum products.

Gypsum board products consist of a plaster core between two layers of paper. The core is made of stucco of less exacting specifications than that required for most other plaster products. Gypsum containing 85 percent $CaSO_4 \cdot 2H_2O$ is commonly used, and material of 80 percent or slightly lower grade has been used satisfactorily. Two plants in California make stucco for board products by flash calcination.

Board products are made by continuous methods on automatic machines that can be adjusted to make any of the standard products. Equipment manufactured by the J.C. Ehrsam and Sons Manufacturing Company is very commonly used. Almost all plants use very similar machines modified to their own specifications.

Wallboard is made as a single continuous strip, but when making the narrower lath the machine forms three parallel strips. The special papers that form the outer layers of the strips are drawn from stock rolls at the head the machine. Stucco for the core is usually brought in a screw conveyor to a platform over the head of the machine where carefully measured amounts of additives are fed into the conveyor and mixed with the stucco.

The additives usually include an accelerator. One California plant uses ground set plaster, another salt water, and a third ground gypsum and potassium sulfate. An important additive is starch or corn flour to promote the sticking of the plaster to the paper. These materials coat the fine gypsum crystals that penetrate the paper and prevent them from calcining during drying. Wood flour, or less commonly chopped paper, is added for a filler. Increased porosity is provided by the addition of soap or other means for entraining air into the wet plaster. The dry ingredients are mixed with water in an Ehrsam type pin mixer. Practice varies, but one California wallboard manufacturer who is no longer active stated that the requirements for 1000 square feet of $\frac{3}{8}$-inch board were:

Stucco	1500 pounds
Water	250 pounds
Wood flour	100 pounds
Starch	10 pounds
Soap	2 pounds

The slurry of wet plaster is placed on the moving bottom paper, and the top paper is fed on immediately ahead of the forming rolls that fold over the projecting edges of the bottom paper and seal them to the top paper with an adhesive. When wallboard and sheathing board are made, the bottom paper is scored with carborundum wheels in order that the folded edges will be shaped correctly; but for lath, which has rounded edges, the bottom paper is not scored.

The green board, which moves at a constant speed, is supported on a moving belt, until it has partly set. For the remainder of the length of the machine it moves on rollers, every third one of which is belt-driven. Guides are provided at intervals to keep the board in position. Near the end of the machine is the reciprocating Ehrsam punch that moves hori-

zontally and makes the key holes in perforated lath. Beyond the punch a revolving knife cuts the continuous strip into lengths that are whisked away at an accelerated speed to the end of the machine. The distance from the forming rolls to the cut-off knife ranges from under 500 feet to over 600 feet.

Drying is accomplished by passing the lengths back through a Coe drier placed parallel with the board machine. A fully automatic system of transfer belts moves them to an elevator or hinged loading ramp that feeds them two at a time into the proper deck of the drier. The key hole punch, the cut-off knife, the transfer belts, and the loading ramp are synchronized and are controlled by switches actuated either by fingers that contact the lengths of board or by electric eyes.

Driers have six or eight decks of rollers, each wide enough to accommodate two lengths of wallboard or six lengths of lath. They are divided into three or four sections through which air is forced. Heat is provided by steam coils beneath the decks or by gas burners in the air intakes. Temperatures of 300° to 350°F. are maintained in the first part of the drier. This is reduced to 250°F. or less in the end section to eliminate the possibility of recalcining.

In some plants the finished wallboard and lath are unloaded and stacked by equipment similar to the loading ramp, but at other plants unloading and stacking are done by hand. These operators feel that hand unloading provides an opportunity for closely inspecting that justifies a possible increased breakage caused by carelessness.

The following products are made by most board plants.

Gypsum Wallboard. Gypsum wallboard is for walls and ceilings. It is fastened directly onto the wood framing or furring blocks and may be painted or papered. Most wallboard is $\frac{3}{8}$ inch thick, but there is $\frac{1}{2}$-inch wallboard also that possesses 40 percent greater strength. Both $\frac{3}{8}$- and $\frac{1}{2}$-inch wallboard are available in 4-foot widths and lengths of 6, 7, 8, 9, 10 and 12 feet. Both are available with recessed edges for use with reinforcing tape and cement to conceal the joints, beveled edges for decorative effects, or square edges. There is also $\frac{1}{4}$-inch wallboard for curved surfaces, repair work, or lining sheds that is available in lengths of 7, 8, 9, and 10 feet. The $\frac{1}{4}$-inch wallboard is made with square edges only.

Gypsum Lath. Gypsum lath is $\frac{3}{8}$ inch or $\frac{1}{2}$ inch thick, 16 inches wide, and 4 feet long. Lath has round edges. It is available either plain, perforated, or with a sheet of aluminum foil cemented to the back side for insulation against heat and cold.

Gypsum Sheathing. Gypsum sheathing is a water-repellent, windtight sheathing material intended for use without building paper. It is made with special water-resistant paper and has tongue and groove edges. Gypsum sheathing is available in sheets $\frac{1}{2}$ inch thick, 2 feet wide, and 8 feet long.

Gypsum Tile. Gypsum tile has been in use for over 30 years, but consumption is minor compared with that of other gypsum products used by the building industry.

Tile is cast in steel molds by mass production methods. Standard tile is 30 inches long, 12 inches wide, and available in a number of thicknesses. There are also specially shaped tiles for use as shoe and soffit tile with

structural steel. Solid tile 2 inches and 3 inches thick is available, and hollow tile, which contains symmetrically spaced holes parallel to the length, is available in 3-, 4-, 5-, and 6-inch thicknesses. Furring blocks 1½ inch or 2 inches thick are made by splitting hollow tile. Tile is readily cut with the plaster saw, which has large teeth. Only gypsum mortar, which consists of neat plaster mixed with up to 3 parts by weight of sand, can be used with tile.

The principal uses for gypsum tile are for non-load-bearing interior partitions and for fireproofing structural steel. Gypsum tile is particularly adapted to buildings in which partitions must be frequently altered to meet changing requirements. In protecting steel beams, columns, and girders from fire, 2- or 3-inch tile are built around the member. Hollow spaces may be backfilled, and additional protection is provided by plastering the outside. In tests made by the Bureau of Standards loaded test columns protected with gypsum tile and subjected to a temperature of 2200°F. failed after 2½ to nearly 7 hours. The thickness of the tile, the use of solid or hollow tile, and the presence of plaster account for this range in time to failure.

Reinforced Gypsum Concrete

Reinforced gypsum concrete is a building material used in comparatively small quantities that was approved for use in 1941. It consists of plaster mixed with up to 12½ percent by weight of wood fiber, chips, or shavings; and it is reinforced with concrete reinforcement bars or wire. Minimum compressive stresses specified by the American Standards Association are:

Neat	1800 pounds per square inch
Containing up to 3 percent wood fiber	1000 pounds per square inch
Containing up to 12 percent wood fiber	500 pounds per square inch

Reinforced gypsum concrete is either used as precast units or cast in place. Roof tile is 3 by 12 by 30 inches. Gypsum planks are either plain edged or have metal tongue and groove edges. The plain edged planks are 2½ inches thick, 10 inches wide, and 6 feet long. Metal edged planks are 2 inches thick, 15 inches wide, and 6, 8, or 10 feet long.

When reinforced gypsum concrete is poured in place two systems may be used. In one a permanent form of wallboard is built, steel reinforcement is placed, and the gypsum concrete is poured on it. In the suspension system parallel and uniformily spaced cables are stretched over the roof or floor beams and securely anchored at the ends. Forms are placed beneath the cables. and at least 3 inches of gypsum concrete is poured, enclosing the cables.

Industrial Plasters

A comparatively small volume of high priced calcined gypsum products is produced for industrial use. Some are specialties that are made at only a few plants for the entire United States market; others, used in greater quantities, are produced by the majority of plaster manufacturers. In general, industrial plasters have higher strength than most building plasters and medium to quick setting times.

Strength of plaster is closely related to consistency because a plaster of high consistency is porous after it has set and dried. Ordinary plaster is mixed with a quantity of water enormously greater than that required

for hydration. The normal consistency of hardwall plaster is 80 to 100 milliliters of water per 100 grams of plaster, while the theoretical amount of water for rehydration is only 18.6 milliliters. By artificial aging, the normal consistency of kettle stucco can be reduced to between 60 and 75 milliliters. Aged stucco reground with buhr mills is used for some industrial plasters.

There are a number of patented methods for producing high-strength plaster of very low consistency. Hydrocal is made by treating lump gypsum in an autoclave with saturated steam at 15 pounds pressure for 6 hours. The calcined product, after drying and grinding, has a consistency of 45 milliliters. Certrock is kettle stucco to which is added 1 to 2 percent of gum arabic and an alkali such as lime, litharge, or soda ash. The consistency approximates that of Hydrocal. Hydrostone, made by treating Hydrocal with gum arabic and alkali, has a consistency of 27 milliliters. In making Hydromite a carbamide-formaldehyde resin is added that still further reduces the amount of excess water taken up by the plaster. A process developed by Eberl and Ingram [84] consists of autoclaving a slurry of finely ground gypsum to which is added about 0.1 percent of a dicarboxylic acid salt. Microscopic studies showed that these salts cause the hemihydrate crystals to have the shape of short rods that can pack closely. A limited amount of grinding following autoclaving increases the powder density, apparently by rounding the sharp corners of the crystals; but prolonged grinding produces fluffy particles.

Casting Plaster. Casting plaster is used for ornamental statuary and interior decoration because it expands slightly upon setting. The properties desired are high strength, low heat of hydration in order not to harm the molds, and quick setting time. It is prepared by regrinding artificially aged kettle stucco.

Pottery Plaster.[85] Pottery plasters are special plasters used by the ceramics industry in the manufacture of dinner ware and sanitary ware. They are used as modeling and patterning mediums and in making master dies and production molds. Gypsum plaster is suitable for these purposes because of its ability to receive and transmit to other media surface detail, to retain dimensional accuracy, and to absorb moisture.

Pottery plaster is a plaster of low consistency and high strength. Since 1932 a number of special pottery plasters have been developed that contain a high proportion of alpha $CaSO_4 \cdot \frac{1}{2}H_2O$. In compressive strength they range up to 15,000 pounds per square inch, in expansion from 0.0 percent to 1.5 percent and in absorption characteristics from 2 percent to more than 50 percent. Improvements in pottery plaster have made possible improvements in mold shop practice.

In pottery plants particular attention should be paid to the storage of plaster to prevent its absorbing moisture. Enclosed storage to prevent the free circulation of air should be provided, and the temperature should be kept above the dew-point. Mixing is usually done with mechanical mixers to produce slurries free from entrained air, and in a few cases vacuum mixing is practiced. New molds are dried before use,

[84] Eberl, J. J., and Ingram, A. R., Process for making high-strength plaster of Paris: Ind. and Eng. Chem., vol. 41, pp. 1061-1065, May 1949.

[85] Wiss, J. E., Recent developments in the use of gypsum plasters in ceramics: Pacific Coast Ceramic News, vol. 1, no. 10, pp. 13, 17, April 1951 and vol. 1, no. 11, p. 14, May 1951.

and used molds are dried before being used again. In storing molds slow calcination may take place if the temperature is greater than 120° F. and the relative humidity is less than 10 percent.

Plaster for the Plate Glass Industry. The plate glass industry uses plaster for holding the glass during polishing. Plaster for this purpose must be finely ground and contain no impurity that could scratch the glass. Strength is relatively unimportant.

Dental and Orthopedic Plasters. United States consumption of dental and orthopedic plasters is only a few thousand tons a year. Dental plasters have high tensile strength and are available with setting times ranging from 2 to 40 minutes. Low heat of hydration is essential.

Industrial Casting and Molding Plasters. Special high-strength plasters such as Hydrocal are used for tooling and pattern work requiring great dimensional accuracy. For less exacting work casting plaster made from kettle stucco is used.

Minor Uses of Gypsum

In addition to its principal uses, small quantities of gypsum totaling less than 50,000 tons a year for the entire United States are consumed for other purposes. Finely ground, white, uncalcined gypsum, called terra alba, is a cheap material that is chemically neutral. As a filler, it is used in paper, textiles, paint, plastic articles, and blasting powder. As a diluent and carrier, it is mixed with drugs and chemicals. Relatively small quantities compared with talc and pyrophyllite are used in insecticides. Crown filler, artificially precipitated $CaSO_4 \cdot 2H_2O$, is used in paper and cloth. Breweries use powdered gypsum for conditioning water. Mixed with a binder, powdered gypsum is made into blackboard chalk.

An industrial drying agent is prepared by calcining gypsum for 3 hours at 460° F. The product, which is soluble anhydrite, can be regenerated by reheating. Calcined gypsum is also used as a fireproof filling for safes and filing cabinets and as an ingredient of match heads.

In some countries, but not in the United States, substantial quantities of gypsum are used in metallurgy and in chemical processes. It is used as a flux in smelting the nickel ores of New Caledonia, in the Carmichael-Bradford processes for the blast roasting of galena, and for concentrating lead-copper matte in Germany.

In England, France, and Germany ammonium sulfate is prepared by reacting ammonia and carbon dioxide with ground gypsum in water. After the calcium carbonate that precipitates has been removed, the solution is evaporated to recover the ammonium sulfate.

The current sulfur shortage has created renewed interest in gypsum as a source of sulfur compounds, and there are a number of processes for making sulfuric acid from gypsum or anhydrite. An English plant is described in the anhydrite section of this paper. Most of the processes produce cement clinker and SO_2 gas that is made into sulfuric acid, but recently a United States patent has been issued on a process [86] in which, by means of a catalyst, hydraulic cement and sulfur trioxide are produced.

In India the recovery of sulfur from gypsum is under consideration.[87]

[86] Rock Products, New products from gypsum: Rock Products, vol. 54, no. 2, p. 77, February 1951.

[87] Chem. and Eng. News, India may produce sulfuric acid from gypsum: Chem. and Eng. News, vol. 29, no. 5, p. 392, 1951.

Uses of Anhydrite

Anhydrite, commonly associated with gypsum, is found in most of the extensively developed gypsum deposits. In California abundant anhydrite has been encountered only in the workings of the United States Gypsum Company in the Little Maria Mountains and in the Fish Creek Mountains. Other deposits where further exploration might reasonably be expected to find anhydrite are the Palen Mountains, Riverside Mountains, and Cuyama Valley deposits.

Although many gypsum mines could produce large quantities of anhydrite, few uses for anhydrite have been developed; and comparatively small quantities are sold. For some purposes anhydrite can be substituted for gypsum. Probably the largest amount is used in agriculture. Anhydrite from Nova Scotia is used as a source of calcium and sulfur for peanut crops in Virginia. In California some high grade agricultural gypsum contains anhydrite. The treatment of alkali and adobe soils with anhydrite has received little study, although the experiments of G. E. Colby [88] showed that both anhydrite and gypsum are equally effective in neutralizing black alkali (sodium carbonate). The State Bureau of Chemistry has noticed no indication that anhydrite and gypsum are not of equal value, and as yet it has not been necessary to distinguish between them.

The portland cement industry has devoted much study to the substitution of anhydrite for gypsum as a retarder. Today anhydrite is not used generally, although one California portland cement producer has used substantial quantities of anhydrite. The published reports of the studies made appear to be incomplete and inconclusive, but all investigators agree that anhydrite cannot be indiscriminately substituted for gypsum even though the sulfate radical is the active component of the gypsum. Presumably differences in solubility and rate of dissolution account in part for the differences in their behavior. Laboratory experiments [89] do show that for some cements between 25 and 70 percent of the sulfate added may be in the form of anhydrite.

Anhydrite may be advantageously substituted for gypsum in most of the chemical and metallurgical processes requiring calcium sulfate because of its higher calcium sulfate content and lack of water of hydration. Little if any calcium sulfate is, however, so used in the United States.

In Germany and England large quantities of both gypsum and anhydrite are used in making ammonium sulfate. At Billingham, England both sulfuric acid and portland cement are made from anhydrite in an integrated operation.[90] Anhydrite is reduced to sulfur dioxide with coke in a cement kiln, and the correct amount of clay and siliceous material is added so that the residue has the composition of portland cement clinker. The sulfur dioxide is purified and converted to sulfuric acid.

Much work has been done on making plaster from anhydrite, and some anhydrite plaster is used in England. Finely ground anhydrite sets very slowly with water, and most of the investigations have been concerned

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[88] Colby, G. E., A note on the use of anhydrite as a remedy for black alkali: California Dept. Agriculture Bull. 10, no. 1, pp. 39-41, 1921.

[89] Hansen, W. C., and Hunt, J. O., The use of natural anhydrite in portland cement: Am. Soc. Test. Materials, Bull. no. 161, pp. 50-57, October 1949.
Roller, P. S., and Halwer, Murray, Relative value of gypsum and anhydrite as additions to portland cement: U. S. Bur. Mines Tech. paper no. 578, 15 pp., 1937.

[90] Stewart, G. E., Billingham mine: Inst. Min. Met. Bull. 480, pp. 1-11, Sept. 1946.
Cole, L. H., and Rogers, R. A., Anhydrite in Canada: Canada Dept. of Mines, Mines Branch, no. 732, p. 30, 1933.

with the addition of suitable accelerators. The Canada Department of Mines conducted an exhaustive series of laboratory tests [91] on making plaster from anhydrite from numerous Canadian deposits. By the addition of small quantities of metal salts to finely ground anhydrite, plasters were made having approximately the properties of Keene's cement. Many of the reagents tested produced plasters with high shrinkage and great efflorescence, but the most satisfactory results were obtained when two reagents were used. The tests indicated further that anhydrite from different deposits required different proportions of reagents.

Some work has been done on making high strength cement by calcining anhydrite.

Other minor uses for anhydrite are for some fillers, carriers, and diluents. Pearl filler is finely ground anhydrite.

Gypsum Markets

Gypsum, like many non-metallic minerals, is a low-priced, widely distributed commodity that is of value only when it may be economically transported to consuming centers. Freight charges represent in many cases half or more of the price the consumer pays. Although there are large undeveloped gypsum deposits in the state, California production is estimated to be but three-quarters of consumption. Most of the gypsum produced in California is consumed in the southern part of the state, and even in southern California appreciable quantities of gypsum are brought in from Mexico and Arden, Nevada. Northern California is supplied almost entirely with gypsum from Mexico and Gerlach, Nevada.

The California production of gypsum is shown in figure 10. Since statistics were first recorded in 1887, the production has reflected the growth in population and in industrial activity. Most outstanding is the enormous increase within the past 10 years, which was caused both by a sharp rise in building activity and by the large scale use of gypsum for treating alkali soils that began about 1940.

The plaster industry, agriculture, and the portland cement industry are the major consumers of gypsum in California. The plaster industry is dominated by large integrated companies that own their own gypsum mines and have reserves for many years. Competition between companies and between the plaster industry and manufacturers of other building materials is keen. Large amounts of capital are required for the construction of calcining and wallboard plants. Expenditures of $1\frac{1}{2}$ and two million dollars have been reported [92] for the building and reconstruction of plants outside of California.

In California there are five calcining plants. One is in the San Francisco Bay area, two are near Los Angeles, and the remaining two are in the southeastern desert close to gypsum deposits. The three metropolitan plants obtain gypsum from outside of the state. The Bay area plant and one of the Los Angeles plants produce board products only. In addition, plaster and board products are brought in from Gerlach and Arden, Nevada.

Most of the agricultural gypsum is consumed in the San Joaquin Valley. Ninety percent of this gypsum is gypsite produced within 150

[91] Cole, L. H., and Rogers, R. A., Anhydrite in Canada: Canada Dept. of Mines, Mines Branch, no. 732, pp. 35-80, 1933.
[92] Mining World, vol. 11, no. 7, p. 50, June 1949.
Pit and Quarry, vol. 41, no. 7, p. 98, January 1949.

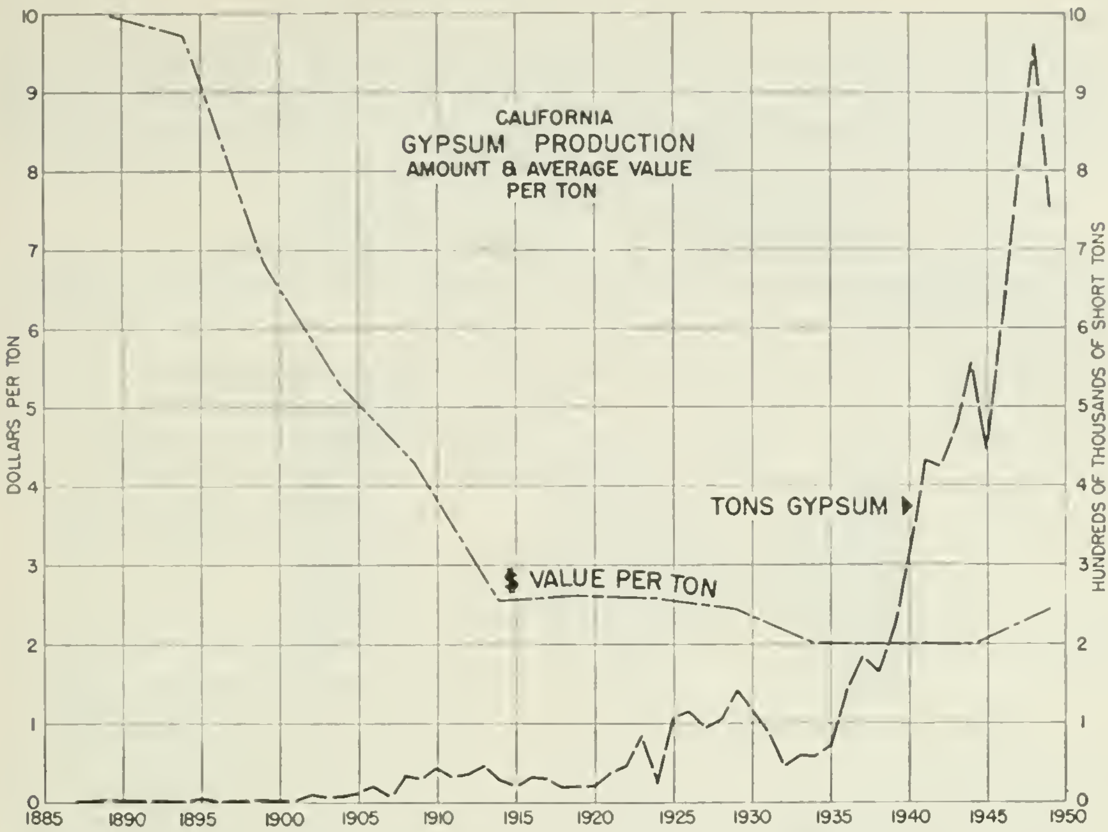

FIGURE 10. Chart showing production and average price of gypsum in California.

miles of the farms; the remainder is ground rock gypsum most of which is mined in southern California. Elsewhere in California, ground rock gypsum is used exclusively. That sold in northern California comes from Nevada, while gypsum sold in the Imperial Valley is produced in California.

The agricultural market is relatively favorable for the small producer. Producers must, however, comply with the regulations of the Department of Agriculture, which are discussed in another section of this study. The mortality among producers of agricultural gypsum has been high and probably the greatest single cause is failure to produce gypsum of the guaranteed quality.

Most of the portland cement plants purchase gypsum from plaster companies. Only two California plants obtain gypsum from their own deposits, and of these, one is a major producer of calcined gypsum products as well as portland cement. In addition, two companies own deposits from which there has been no production. Plants in northern California use gypsum from Mexico, and Gerlach, Nevada, supplemented by synthetic gypsum made in the Bay area, while southern California plants use gypsum from California and Arden, Nevada.

The portland cement industry is a relatively unfavorable market for the small gypsum producer. Portland cement plants desire a uniform and dependable supply of gypsum, and many are reluctant to jeopardize their existing sources unless a long-term guarantee is furnished. The producer must also find a market for off-grades and sizes of gypsum that are not acceptable to the portland cement plant.

Although the average value of gypsum at the mine is reported to be $2.45 a ton by California producers, most figures for rock gypsum are

nominal. The only California production costs available are those of the Inca operation, which is described in another section of this study. There the cost of mining was $1.50 a ton. Preparation of bulk gypsum (ground to 100 percent minus 10 mesh) cost less than $1.50 a ton, and sacked gypsum (100 percent minus 50 mesh), $4.50 a ton.

The price of gypsite is about $1.75 a ton at the mine.

Freight charges are equal to or greater than the price at the mine. The following representative rates on crude gypsum were in effect in February 1951.[93]

Rail carload rates (in cents per 100 pounds or per ton in open top cars).

To	From	Rate (cents)	Minimum weight (pounds)	Remarks
Los Angeles	Midland	324 per ton	40,000	
	Midland	292 per ton	80,000	Santa Fe direct
	Plaster City	324 per ton	40,000	
	Plaster City	292 per ton	80,000	
	Maricopa	15 per 100 pounds	30,000	
Fresno	Midland	454 per ton	40,000	Santa Fe direct
	Midland	497 per ton	40,000	Does not apply via Santa Fe direct
	Plaster City	454 per ton	40,000	San Diego-Ariz., via El Centro, Southern Pacific
	Plaster City	497 per ton	40,000	San Diego-Ariz., via El Centro Southern Pacific, Colton or Bakersfield, Santa Fe
San Francisco	Maricopa	28 per 100 pounds	30,000	

Truck Load Rates

To	From	Rate (cents)	Minimum weight (pounds)	Remarks
Los Angeles	Midland	18 per 100 pounds	40,000	Dock to dock
	Midland	24½ per 100 pounds	40,000	If no rail track or truck dock
	Plaster City	21 per 100 pounds	30,000	
	Maricopa	19 per 100 pounds	40,000	
Fresno	Midland	52 per 100 pounds	40,000	Dock to dock
	Midland	58 per 100 pounds	40,000	If no rail track or truck dock
	Plaster City	36 per 100 pounds	30,000	
San Francisco	Maricopa	60 per 100 pounds	40,000	

Agricultural gypsum may be sold at the mine, but the price usually includes delivering the gypsum to the farm and sometimes spreading it on the fields. In the San Joaquin Valley 50 to 70 percent gypsite costs between $6.00 and $7.00 a ton delivered and spread. Ground rock gypsum costs $14.00 a ton delivered or up to $18.00 a ton if the cost of spreading is included. It is apparent that the cost of hauling and handling agricultural gypsum is several times its value at the mine. Considering the cost per unit of gypsum, the handling charges of gypsite increase rapidly with decreasing gypsum content. At a comparatively short distance from

[93] Data supplied by W. G. O'Barr, Los Angeles Chamber of Commerce.

the mine the cost per unit of gypsum in gypsite equals that of high-grade rock gypsum. Actually 70 percent gypsite from Kern County is sold as far north as Livermore. In a similar way, the 30 and 40 percent gypsite from Fresno County has a still more limited range.

GYPSUM PLANTS IN CALIFORNIA

Kaiser Gypsum Division, Long Beach Plant[94] (54). The Long Beach plant of Kaiser Gypsum Division of Kaiser Industries Inc. is at 1301 Water Street on the Long Beach waterfront. The property was purchased from the Standard Gypsum Company in 1944, and enlargement and modernization was completed in the summer of 1947. The chief products are gypsum wallboard and lath, hardwall plaster, gaging plaster, and finishing plaster.

Raw gypsum is brought from the Kaiser Company's San Marcos Island deposit in the self-unloading ship "Permanente Silverbow." The gypsum, a hard, fine-grained material crushed at the mine, contains so little free moisture that drying before grinding is not necessary. Covered storage is provided at the plant.

Gypsum from the stock pile is crushed in a Pennsylvania hammer mill and then ground to about 78 percent minus 100 mesh with Raymond high-side roller mills in closed circuit with air separators. The Raymond mill product is fed to three gas-fired Ehrsam calcining kettles, each of 10 tons capacity. The calcining time is about 2¼ hours, and the maximum temperature is between 340° and 350° F. The kettles are equipped with recording pyrometers to facilitate close temperature control. After calcination the kettle charge is dumped into the hot pit. When it has cooled the stucco is elevated to bins in the plaster section of the mill or carried to the wallboard section with 8-inch screw conveyors. Because of the plant's location in an intensely developed area, special precautions are taken to avoid contaminating the atmosphere with dust. Air from the Raymond mills passes through cloth filters after leaving the air separators. Each hotpit is vented to its kettle, and the kettle stacks are equipped with water sprays that wash the dust out of the mixture of dust and steam given off during calcination.

Stucco for hardwall plaster is reground in a Marcy 5 x 20-foot tube mill, while stucco for casting plaster is reground in buhr mills in closed circuit with Whizzer dust separators. Reground stucco is conveyed to bins located above weighing hoppers where retarder, fiber, aggregate, or other ingredients are added. One-ton batches from the weighing hoppers are mixed for 3 minutes in Ehrsam paddle-type mixers and then packed in 100-pound paper bags.

Gypsum board products are made on a 493-foot machine designed cooperatively by the J. B. Ehrsam and Sons Manufacturing Company and the Henry J. Kaiser Company. Stucco is taken directly from the hotpits to the board plant with screw conveyors and stored in cylindrical tanks with conical bottoms. Stucco from the storage tanks passes through a mixing screw conveyor where dry ingredients are added with Syntron electric vibrating feeders. Water is added in a pin-type mixer at the head

[94] Newest plaster board plant on west coast: Rock Products, vol. 50, no. 9, pp. 74-77, September 1947.
Utley, F. H., "World's richest gypsum quarry" supplies new board plant: Pit and Quarry, vol. 40, no. 3, pp. 114-117, 124, September 1947.
Plant visit January 1949.

of the machine. The green board from the forming rolls is supported for 255 feet on a 57-inch conveyor belt and then on rollers. The punch for making holes in perforated lath and the cut-off knife are of the Ehrsam type. The punch, knife, transfer section, and loading ramp for the drier are synchronized with Selsyn and electric eye controls. Board is dried in a Coe drier having eight decks. Finished board is removed by hand, inspected, and bundled.

Kaiser Gypsum Division, Redwood City Plant[95] (98). The Redwood City plant of the Kaiser Gypsum Division, Kaiser Industries, Inc., manufactures gypsum board and lath products for the Bay area and the northern California market. Ernest Schaper is the plant superintendent, the superintendent of the wallboard plant is Lawrence E. Hays, and Wallace C. Riddell is Director of Research. Built by the Pacific Portland Cement Company in 1941, the plant was taken over by the Kaiser interests in October 1949. It is located at the Port of Redwood City where crude gypsum is brought in Kaiser ships from the San Marcos Island deposit and stockpiled near the plant.

The crude gypsum as received at the wallboard plant is 2 to 3 inches in size and averages 96½ percent gypsum. Trucks deliver it from the stockpile to a hopper from which it is fed to a jaw crusher that reduces it to half-inch size. The former operator calcined a mixture of natural and synthetic gypsum, but this practice has been abandoned. It is believed that difficulty encountered in calcining the synthetic material may have been caused by a coating of magnesium hydroxide.

Calcining is accomplished with three number 50 Raymond Imp kiln mills driven at 1850 rpm by 50-and 60-horsepower motors. The temperature of the furnace gases is 1400°F., and the stucco is withdrawn from the mills at 360° to 410°F. and 90 to 95 percent minus 100 mesh. Stucco is stored in cylindrical steel storage bins.

Stucco is withdrawn from the bins with drag conveyors, passed through a revolving half-inch screen to remove foreign matter, and brought to the mixing platform over the head of the Ehrsam board machine. Carefully measured amounts of additives are introduced into the screw conveyor with Gump feeders located on this platform. An Ehrsam type pin mixer is used to mix the dry ingredients with water. This board machine is provided with guides placed at intervals to keep the board in position. Talc powder is put on the top surface of the board to facilitate later handling. The switches that control the cut-off knife, transfer belts, and loading ramp are actuated by fingers that contact the lengths of board.

The Coe drier has six decks and is divided into three sections. Heat is provided by steam coils in the first and second sections and by gas burners in the air intakes to the second and third sections. The temperature in the first section is from 320° to 350°F., about 360°F. in the second, and 250°F. in the third. Finished wallboard and lath is removed from the drier, inspected closely for quality defects, placed face to face; and the ends are sealed with paper tape. Then the bundles are placed in the warehouse or stacked in box cars for shipment.

At present the plant is operating 24 hours a day, 7 days a week, at a capacity that has been increased nearly 50 percent during the past year.

[95] Plant visit January 1951.

Monolith Portland Cement Company, Quatal Canyon Gypsum Operation[96] (109). The Quatal Canyon gypsum operation of the Monolith Portland Cement Company is on the north side of Quatal Canyon about 5 miles east of Ventucopa, a post office and store in the upper Cuyama Valley. Gypsum for the company's portland cement plant at Tehachapi is produced here. Mining began in 1941.

The gypsum bed has been opened by two small quarries in a branch canyon close to the lower edge of an extensive dip slope. The bed is 10 to 15 feet thick here, and it is covered by up to 15 feet of soft clay shale. After the overburden has been removed with bulldozers, the gypsum is drilled with jackhammers and blasted. A power shovel loads the gypsum into dump trucks for the haul to the crushing plant about a quarter of a mile away near the mouth of the branch canyon.

At the crushing plant the trucks dump the gypsum on a grizzly with widely spaced bars; and the oversize is broken up on the grizzly with an air operated gad. The gypsum then passes over a second grizzly, and the oversize is reduced to about 1½ inch with a jaw crusher. The crusher product and grizzly undersize are stockpiled over a timbered draw point by means of a belt conveyor. A second belt conveyor is used to load trucks from the draw point. The crushed gypsum is hauled in large diesel trucks with trailers to Maricopa where it is loaded into railroad cars that take it to Tehachapi.

Monterey Gypsum Company[97] (76). The Monterey Gypsum Company was the most recent of a number of enterprises that operated the Mule Shoe Ranch deposit, San Benito County. During 1945 and 1946 ground rock gypsum for agricultural use was produced in a plant just west of the Bitterwater road 14 miles from King City. The product was guaranteed to contain 85 percent $CaSO_4 \cdot 2H_2O$. The operation is abandoned and the equipment removed.

The gypsum body worked in 1945 was a flat-lying lens near the top of a low ridge half a mile north of the plant. Up to 8 feet of slightly consolidated overburden was stripped before the gypsum was drilled and blasted. A truck-mounted crane equipped with a ¾-cubic-yard clam shell bucket loaded the broken gypsum into a truck of 6 cubic yards capacity.

At the plant the gypsum was crushed to 4-to-6-inch size in a 15- by 38-inch jaw crusher and ground to 90 percent minus 100 mesh in a Gruenler hammer mill in closed circuit with a Raymond air separator. Shipments of both bulk and sacked gypsum were made. Capacity of the plant was 200 tons in 8 hours.

Pabco Products, Inc., South Gate Board Plant[98] (57). The Paraffine Companies, Inc. produces Pabco wallboard, lath, and sheathing board in a plant at 4231 Firestone Boulevard, South Gate. Gypsum is brought by rail from the company's deposit near Las Vegas, Nevada. The small amount of impurities contained in the gypsum consists primarily of limestone.

At the plant the gypsum is screened after magnets remove tramp iron. Plus ¾-inch material is ground in a Williams mill, and the ground gypsum goes to storage bins. Stucco is produced in four Raymond Imp kiln mills.

[96] Plant visit May 1950.
[97] Averill, C. V., Mines and mineral resources of San Benito County, California: California Jour. Mines and Geology, vol. 43, p. 51, 1947.
[98] Plant visit January 1949.

Gases and steam from the cyclone separator pass through a Cottrell precipitator for the removal of dust before being discharged into the atmosphere.

Board products are made on an Ehrsam machine. The dry additives are measured into the screw conveyor that brings the stucco to the pin-type mixer where water is added. When lath is made the cut-off knife scores the lath every four feet and cuts it into 12-foot lengths. The long sections are broken into four-foot lengths as they come from the drier. The drier, a Coe machine, has eight decks and is divided into three sections. The finished lengths are taken from the drier, alternate sections turned over, and stacked mechanically.

United States Gypsum Company, Plaster City Plant (28). One of the largest gypsum plants in California is the United States Gypsum Company's operation at Plaster City, Imperial County. Gypsum is brought by rail from the company's quarry in the Fish Creek Mountains about 25 miles to the north. The United States Gypsum Company bought the plant and deposit from the Pacific Portland Cement Company in 1945 and has since rebuilt and modernized the entire operation. H.E. Hammer is Works Manager and J.R. Burns is Quarry and Railroad Superintendent.

No recent description of the quarry or plant is available. The deposit has been opened by a quarry that in 1942 had a face 3000 feet long and an average height of 100 feet above the quarry floor.[99] Several months' supply of gypsum was shot down at one time by blasting a series of holes drilled with an Armstrong churn drill.

United States Gypsum Company, Midland Operation[100] (68). The United States Gypsum Company's plant at Midland, Riverside County, began producing uncalcined gypsum products in 1925. Calcined products were first produced in 1928 in a plant that has since been enlarged. Gypsum comes from the Brown, Victor, and Skelenger mines 1 to 2½ miles to the west and southwest in the Little Maria Mountains. Mr. M.C. Grisham was Works Manager in 1951.

At the Brown mine a gypsum lens that averages 45 feet wide and dips 75° NW. occurs in limestone north of the contact of the limestone with the green schistose rocks. Anhydrite was encountered at a comparatively shallow depth. The upper part of the gypsum body was mined by an open cut 500 feet long and 50 feet wide; the lower part was recovered by over-hand stoping from an inclined shaft sunk to the anhydrite. In 1948 preparations were being made to remove the pillar beneath the pit floor and abandon the mine. Gypsum is hauled to the plant in 3-ton mine cars.

In the Victor mine two gypsum beds 20 to 60 feet thick that dip about 30° NW. have been opened by tunnels. The gypsum beds are separated by quartzite, and the gypsum and quartzite are interbedded with limestone. Anhydrite occurs abundantly at depth and is found at some places within 30 feet of the surface. The gypsum is mined from open stopes driven on 25-foot centers from the tunnels to the surface. About 40 percent of the gypsum is left in pillars that are to be mined later. Drilling is done with

99 Sampson, R. J., and Tucker, W. B., Mineral resources of Imperial County: California Div. Mines Rept. 38, p. 135, 1942.

100 Tucker, W. B., and Sampson, R. J., Mineral resources of Riverside County: California Div. Mines Rept. 41, pp. 170-172, 1945.
Tucker, W. B., and Sampson, R. J., Riverside County: California Div. Mines and Mining, Rept. 25, pp. 513-515, 1929.
Plant visit February 1948.

hammer drills run dry. Broken gypsum is scraped from the stopes with Sullivan slushers and trammed to bins at the entrance to the haulage tunnel.

The Skelenger mine is an open pit operation. Gypsum bodies 60 to 150 feet thick and up to 700 feet long occur in limestone and dip at angles of 20° to 35° NW. Gypsum from the Victor and Skelenger mines is trucked to the plant at Midland where calcined and uncalcined products are made.

At the plant, gypsum is first crushed in a Williams hammer mill and then ground in Raymond mills. There are three calcining kettles, most of whose output is used in the adjoining wallboard plant.

Utah Construction Company, Inca Operation[101] (64). The Inca gypsum operation of the American Gypsum Company and the Utah Construction Company was at Inca Siding in the Little Maria Mountains, Riverside County. Agricultural gypsum was prepared in a plant at Inca Siding from rock gypsum quarried on the Garbutt and Orcutt property and shipped primarily to the Fresno area in the San Joaquin Valley.

The Garbutt and Orcutt property consists of 5 patented claims, Standard Gypsum and Standard Gypsum numbers 2 through 5, in secs. 2, 10, and 11, T. 4 S., 20 E., SBM. These claims were patented before 1919 by the Standard Gypsum Company, but no production was made at this time other than the shipping of bulk samples to Los Angeles for calcining tests. F. A. Garbutt and W. W. Orcutt acquired the property in 1920; it is now owned by the Orcutt estate. In 1945 the Gypsum Products Corporation of San Francisco leased the property and carried out an extensive exploration program. In the most recent operation the deposit was leased by the American Gypsum Company of Fresno who engaged the Utah Construction Company to do the work. In 1948 the Utah Construction Company acquired an interest in the enterprise. Work began in September 1946 and continued intermittently until June 30, 1950 when the operation was abandoned, and the lease was terminated. During this period about 60,000 tons of agricultural gypsum was mined and shipped.

Inca, a siding on the Ripley branch of the Santa Fe railroad, is 20 miles northwest of Blythe and 1½ miles from the Blythe-Midland road. There is no water supply in the vicinity, and that used in the operation was brought in tank cars from Blythe. Electric power is not available. There are no living accommodations at Inca, and most of the men employed there lived at Blythe.

The geology of the Little Maria Mountains gypsum deposits is discussed in detail in an earlier section of this report. Most of the gypsum came from a low hill composed of lenticular gypsum bodies 10 to 20 feet thick that dip about 60°. The gypsum is interbedded with green feldspathic quartzite and schist and a minor proportion of tremolitic limestone. Late in the life of the operation a second quarry was opened in one of the gypsum zones which consist of gypsum interbedded with limestone.

Most of the following data apply to the main quarry.

Most of the exploration was carried out by the previous operator, the Gypsum Products Corporation. In addition to opening the deposit with test pits and trenches, it was explored by 23 diamond drill holes totaling

[101] Plant visit March 1949.

over 3800 feet. The longest hole was 416 feet. Core recovery averaged over 98 percent.

The gypsum body contained a comparatively small amount of interbedded waste, and the broken ore average 90 percent gypsum. Stripping of the overburden of green-colored schistose rocks was necessary however; and it was accomplished with the same equipment used to remove the gypsum. The waste to ore ratio was 1½ to 1.

Blast holes were made with an Ingersoll Rand number 71 wagon drill. Using 1¼-inch steel, holes were drilled to a maximum depth of 20 feet with 5-foot changes of steel. Holes were started with a diameter of 3 inches, and the diameter at the bottom was 2¼ inches. In waste, which had a hardness of 4½, a bit required resharpening after 20 feet, but in gypsum a bit was dulled only after about 500 feet of drilling. An average of 240 feet per drill shift was maintained in gypsum.

At the start of operations a standard round had been devised, but because of the irregularity of the deposit it was found to be impractical. Generally the number of holes was based on the appearance of the face and was modified as drilling progressed. Because of the great difference in hardness between ore and waste the drill runner could readily tell when the bit passed from one to the other. Hole depth ranged from 12 to 20 feet. In waste, holes were spaced on 8-foot centers. In gypsum, however, the hole spacing was limited to 5 feet because with a greater spacing the broken rock contained too high a proportion of fragments that would not pass through the primary crusher.

Holes were loaded with Atlas Amodyn 40 percent dynamite and detonated with Rockmaster electric caps. Zero to 4-delay caps were employed. The caps were connected to the crushing plant power supply or, if that were not available, were set off with a blasting machine. The average consumption of explosive was 0.3 pound per ton of gypsum broken. In an attempt to obtain better fragmentation, up to 1½ pounds of explosive per ton of gypsum were tried, but there was no appreciable improvement.

Two Gardner Denver 055 jack hammers were available for blockholing large boulders. Forty percent dynamite was used and detonated with fuse and number 6 caps. But a minor proportion of the total explosive consumed was for blockholing.

After blasting, a Northwest number 6 shovel of 1½ cubic yards capacity loaded the broken rock into an 8-cubic-yard truck. Waste was hauled to nearby dumps and gypsum to the crushing plant which was at the quarry. Experience indicated, however, that with the comparatively small crusher installed, a ¾-cubic-yard shovel would have been more efficient.

Gypsum was dumped from the 8-cubic-yard truck onto an inclined grizzly with 2-inch openings. A 36-inch Austin-Western pan feeder fed the grizzly oversize to the primary crusher, a 24x36-inch Austin-Western jaw crusher driven by a D-13,000 Caterpillar diesel engine. During the life of the operation wear of the crusher was negligible.

The crusher product and grizzly undersize were carried by a belt conveyor to a stockpile. Gypsum was reclaimed by means of a draw point in a timbered tunnel beneath the stock pile that discharged onto a second conveyor belt. This belt in turn discharged into a 20-cubic-yard truck for the 7-mile haul to Inca Siding. A generator driven by a UD 18 International engine supplied power for the reciprocal feeder and the belt conveyors.

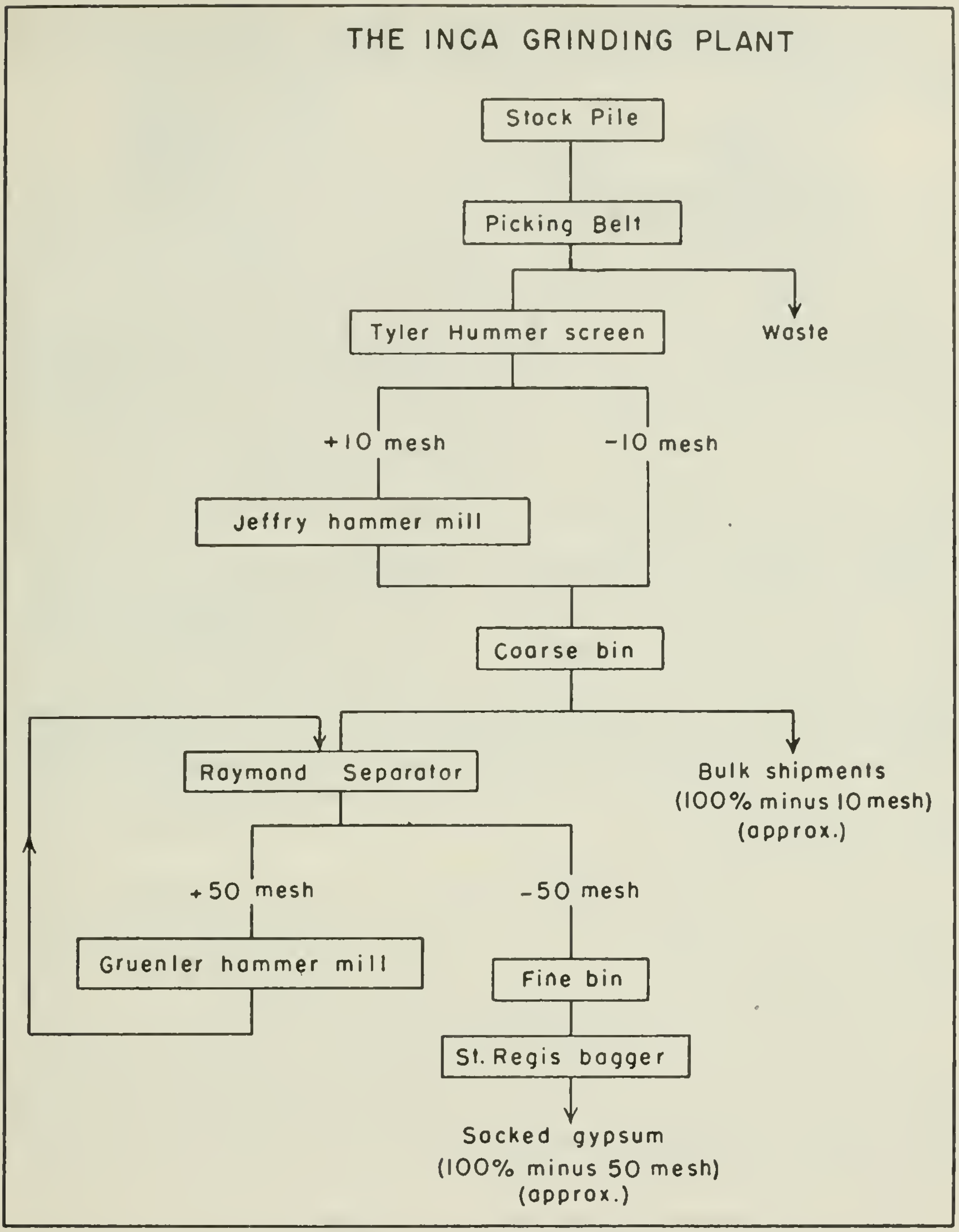

FIGURE 11. Flow sheet of the gypsum grinding plant at Inca Siding.

A stock pile of crushed gypsum built up over a timbered tunnel was maintained at Inca Siding. The screen analysis of the crushed gypsum was as follows:

1½-2 inches	13 percent
1-1½ inches	8 percent
¼-1 inch	12 percent
plus 10 mesh, minus ¼ inch	5 percent
minus 10 mesh	62 percent
Total	100 percent

A belt conveyor from a draw point beneath the stock pile delivered the crushed gypsum to a 4- x 10-foot Tyler hummer screen having two segments. Provision was made for hand picking of waste from this belt. Plus 10-mesh material was separated by the screen and ground in a Jeffry 48-inch hammer mill. The hammer mill product and screen undersize then went to the coarse bin. This material, which was 100 percent minus 10 mesh and about 50 percent minus 50 mesh, was shipped in bulk.

Sacked gypsum was prepared by regrinding the coarse gypsum. A Raymond air separator of 30 tons per hour capacity divided it into a minus 50-mesh fraction that went to the fine gypsum bin and a plus 50-mesh fraction that was reground in a Gruenler hammer mill. The gypsum was sacked with a St. Regis machine. The size of the sacked gypsum was 100 percent minus 50 mesh and 82 percent minus 100 mesh. Capacity of the plant was 50 tons per hour of coarse (bulk) gypsum or 7 tons per hour of sacked gypsum. Both products were guaranteed to contain 93 percent gypsum. Power for the grinding plant was supplied by a 240-kilowatt GMC diesel electric plant.

The cost of mining averaged about $1.50 a ton. Grinding of bulk gypsum cost somewhat less than $1.50 a ton. Sacked gypsum, however, cost $6.00 a ton including the cost of mining. The freight rate to Fresno rose from $3.40 a ton in 1947 to $5.00 a ton in January 1951. The average rate during the life of the operation was about $4.00 a ton.

Five to 22 men were employed depending on the rate of operation, and of these five were employed at the grinding plant. There were in addition a superintendent in charge of the entire operation and a bookkeeper. These men worked one 8-hour shift a day which was occasionally extended to up to 4 hours overtime.

Westvaco Synthetic Gypsum Plant.[102] Synthetic gypsum is a byproduct of several chemical processes. Much of the synthetic gypsum produced in the United States is manufactured in connection with the phosphate industry, but there are no such plants in California. The California material is a byproduct of magnesia produced from salt works bittern that is made at the Newark plant of the Westvaco Chemical Division, Food Machinery and Chemical Corporation.

At the Newark plant bittern, which is obtained from the neighboring solar salt works of the Leslie Salt Company, has the following composition:[103]

[102] Seaton, M. Y., Production and properties of the commercial magnesias: Am. Inst. Min. Met. Eng., Tech. Publ. no. 1496, pp. 12-15, 1942.
Davis, F. F., Mines and mineral resources of Alameda County, California: California Jour. Mines and Geology, vol. 46, pp. 299, 300, 1950.

[103] Seaton, op. cit., p. 12.

	Percent
Sodium chloride	12.5 to 16.0
Magnesium chloride	6.0 to 8.7
Magnesium sulfate	4.2 to 6.1
Potassium chloride	1.4 to 1.9
Magnesium bromide	0.14 to 0.20

Because the supply of bittern is seasonal, storage capacity large enough to hold a year's supply is provided. The recovery of bromine by a modified Kubierschky process is the first step in the treatment of the bittern, but this step does not influence the main operation, and bromine need not be removed.

In the main reaction magnesium hydroxide is precipitated with calcined dolomite:

$$MgCl_2 + \underbrace{Ca(OH)_2 + Mg(OH)_2}_{\text{calcined dolomite}} \rightarrow 2Mg(OH)_2 + CaCl_2$$

In order to prevent contamination of the magnesium hydroxide with gypsum sulfate must be removed before the main reaction. This is accomplished by treating the bittern with the calcium chloride produced in the main reaction.

$$MgSO_4 + CaCl_2 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O + MgCl_2$$

The gypsum, which is recovered by filtration and dried, is a fine grained product of high purity. Most of it is used in the San Francisco Bay area as portland cement retarder and for agricultural purposes.

APPENDIX

CONTENTS

APPENDIX

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TABLES

In the tables of this section, the following abbreviations are used:

Under column headed "Class—production":

"A." Indicates production of more than 100,000 tons
"B." Indicates production of 10,000 tons to 100,000 tons
"C." Indicates production of less than 10,000 tons
"D." Indicates no production except bulk sampling

Under column headed "Class—geological":

"a" indicates gypsite deposit
"b" indicates playa deposit
"c" indicates bedded Tertiary deposit
"d" indicates lens-shaped irregular body in shale
"e" indicates pre-Tertiary deposit
"f" indicates groundwater vein (selenite and satin spar) deposit
"g" indicates hydrothermal deposit
"h" indicates synthetic production

Under column headed "References":

"R" refers to Report of the California State Mineralogist, "B" to a bulletin of the California Division of Mines. In the references that show a name followed by numbers separated by a colon, the name refers to the author, as listed in the accompanying bibliography. The first number is the date of publication of the article, except those following "B," which are bulletin numbers; the second number—that following the colon—is the page reference. A reference given as "Hess 20:83" would refer to an article by Hess published in 1920. The bibliography gives, under "Hess, F. L., the complete data: U. S. Geological Survey Bull. 697, published in 1920. The "83" would refer to page 83 of U. S. Geological Survey Bulletin 697.

Under columns headed "Location":

"B and M" is an abbreviation for "base and meridian"
"SB" refers to San Bernardino base and meridian
"MD" refers to Mt. Diablo base and meridian
"Proj" (for projected) is used after the location if the public land surveys are not complete on the base map.

Under columns headed "Map number":

Numbers listed are those shown on the accompanying map, plate 1.

TABULATED LIST OF CALIFORNIA GYPSUM DEPOSITS

Map No.	Class—production	Class—geological	Name (date of production)	Owner or operator	Location Sec.	T.	R.	B&M	District	References
				Alameda County						
1	D	f	Pendarine mine (coal)		26	3S	3E	MD	Corral Hollow	R88:27
2	A	h	Westvaco Chemical Div. Food Machinery and Chemical Corp. (1938[1])	Westvaco Chemical Div., Food Machinery and Chemical Corp.	11	5S	2W	MD	Newark	Herein; Seaton 42:12-15
				Butte County						
3	D	f(?)	St. Clair mine (hydraulic)		19	21N	4E	MD	Yankee Hill	B38:283
				Colusa County						
4	D	g(?)	Ruby King mine (copper)		29, 32	17N	6W	MD	Little Stony Creek	B38:283
5	D	?	Sulphur Creek		31	17N	7W	MD	Sulphur Creek	B38:283
				Fresno County						
6	C	a	Bahr deposit (1947, 1948)	The Bahr Gypsum Mine[2]	1	16S	12E	MD	Tumey Gulch	Herein
7	C	a	Coalinga mine (1892-1897)	Coalinga Gypsum and Fertilizing Company[2]	21	20S	15E	MD	Coalinga	Watts 94:63, 64
8	C	a	Lillis deposit (1930-1939)	J. C. Lillis	36 2	15S 16S	12E 12E	MD MD	Tumey Gulch	Herein
9	C	a	Little Panoche Placer (1946[1])	Agr. Minerals and Fertilizer Co.[2]	1	14S	10E	MD	Little Panoche Valley	Herein
10	D	a	Monocline Ridge deposit	J. K. Griffin, trustee of H. H. Welsh, deceased	3-10 (incl.)	16S	13E	MD	Monocline Ridge	Herein
11	D	a	Monocline Ridge deposit		19	17S	14E	MD	Monocline Ridge	Anderson et. al. 16:210

12	C	a	Paoli mine (1930-1939) see also Lillis and Tumey Gulch deposits	A. P. Shepard	1, 2	16S	12E	MD	Tumey Gulch	Herein
13	C(?)	a	Panoche #1 and #2	W. J. Hammond	30	14S	12E	MD	Panoche Hills	
14	C	a	San Joaquin Valley mine (1895-1910)	Eureka Gypsum Mines[2]	26	20S	14E	MD	Coalinga	R96:503
			Snow King: see Valley View mine	Dos Palos Gypsum Co.[2]						
15	B	a	Super Gypsum mine (1934-1939, 1947-1950)	Super Gypsum Co.[2], Box 66, Chowchilla	19	14S	12E	MD	Panoche Hills	Fert. Mat. 1948
16	C	a	Tumey Gulch deposit (1892-1900, 1930-1939, 1947-1949)	J. K. Griffin, trustee of H. H. Welsh, deceased, 270 Upland Dr., San Francisco 12	1	16S	12E	MD	Panoche Hills	Herein
17	B	a	Valley View mine (1933-1941, 1948[1])	R. P. Jones, Rt. 4, Box 221, Madera[2]	19	14S	12E	MD	Panoche Hills	Herein
			Valley View Placer: see Super Gypsum	Green and Collins[2]						
				Imperial County						
18	D	c	Blanc deposit	F. L. Blanc	30, 31 6	13S 14S	9E 9E	SB SB	Fish Creek Mountains	Tucker 26:275
			Carrizo deposit: see Blanc deposit and California gypsum group							
19	D	c	California gypsum Group (1920-1927)	California Gypsum Corporation	31	13S	9E	SB	Fish Creek Mountains	Herein
20	D	c	Campbell claims		21	14S	9E	SB	Fish Creek Mountains	Sampson & Tucker 42: Plate 1
			Chaplin deposit: see Tract 67							
21	D	c	Coyote Mountains deposit		24	16S	9E	SB	Coyote Mountain	Sampson & Tucker 42:131
22	C	c	Coyote Mountain Sulfur & Gypsum Deposit	Mrs. Anna Dillon	6	16S	10E	SB	Coyote Mountain	Sampson & Tucker 42:143, 144

TABULATED LIST OF CALIFORNIA GYPSUM DEPOSITS—Continued

Map No.	Class—production	Class—geological	Name (date of production)	Owner or operator	Location Sec.	Location T.	Location R.	Location B&M	District	References
23	A	c	Fish Creek Mountains mine (Imperial Gypsum quarry) (includes Tracts 68, 69, 70, 78, Gypsum King, Hillcrest, El Centro, Gypsum Queen, Swallow, Swallow No. 2, Regent, and South Pole Placers) (1922[1])	United States Gypsum Co. 300 W. Adams St., Chicago 6, Illinois	19, 20, 28, 29, 30, 32, 33	13S	9E	SB	Fish Creek Mountains	Herein
					1, 2, 12	14S	9E	SB		
			Gillett deposit (Tract 78): see Fish Creek Mountains mine							
			Houck deposit: See Tract 71							
			Imperial Gypsum quarry: see Fish Creek Mountains mine							
91			Roberts and Peeler deposit: see San Diego County; not in Imperial County							
24	D	c	Sunshine Placer		6	16S	10E	SB	Coyote Mountains	Sampson & Tucker 42:Plate 1
25	D	c	Tract 67	California Portland Cement Co., 612 S. Flower St., Los Angeles 14	19, 30	13S	9E	SB	Fish Creek Mountains	Herein
			Tracts 68, 69, 70: see Fish Creek Mountains mine							
26	D	c	Tract 71	Blue Diamond Corp., 1650 S. Alameda St., Los Angeles 54	29	13S	9E	SB	Fish Creek Mountains	Herein
27	D	c	Tract 72	Isabelle M. Wilson, RFD 127, Clarksburg	29	13S	9E	SB	Fish Creek Mountains	Herein

			Tract 78: see Fish Creek Mountains mine							
			Ward deposit (Tract 68): see Fish Creek Mountains mine							
29	D	?	Waters deposit	W. H. Waters	4, 5	14S	9E	SB	Fish Creek Mountains	Tucker 26:275
				Inyo County						
30	D	c	Black Mountains deposit	Pacific Coast Borax Division, Borax Consolidated Ltd., 510 W. Sixth St., Los Angeles	6(?)	25N	4E	SB	Ryan	Waring 19:87
31	B	c	China Ranch deposit (Gypsum Rock) (1916, 1917)	Certain-teed Products Corp., 120 E. Lancaster Ave., Ardmore, Pa.	26	20N	7E	SB	China Ranch	Herein
32	D	c	Copper Canyon deposit		NE part	23N	2E	SB	Copper Canyon	Herein
33	D	c	Furnace Creek deposit		SE part	27N	1E	SB	Furnace Creek	Herein
			Gypsum Rock: see China Ranch deposit							
				Kern County						
34	D	a	Buena Vista Lake deposit		6	32S	25E	MD	Buena Vista Lake	Hess 20:73
35	C	a	Cottonwood Creek deposit (1890-1898)	W. A. Fauntleroy	21, 27, 28, 29	29S	30E	MD	Cottonwood Creek	Hess 20:70, 71
36	C	a	Crystal Gypsum Co. deposit (1947, 1948)	Crystal Gypsum Co.[2]	27, 31 35	32S	27E	MD	Kern Lake	Herein
37	C	c	Cuddy Canyon	Unknown	34	9N	21W	MD	Frazier Park	Herein
38	B(?)	a	Gypsum Co. of California deposit (1946, 1947)	Gypsum Co. of California[2]	29	30S	22E	MD	McKittrick	Herein
39	B	a	Handel deposit (1941-1944)	C. Handel Brothers[2]	13	26S	20E	MD	Lost Hills	
40	C	a	Jim's Gypsum mine (1939, 1940)	De Barte and Bohns[2]	31	27S	193	MD	Blackwell's Corner	

TABULATED LIST OF CALIFORNIA GYPSUM DEPOSITS—Continued

Map No.	Class—production	Class—geological	Name (date of production)	Owner or operator	Location				District	References
					Sec.	T.	R.	B&M		
			Kern Lake deposit (see Crystal and Pacific Gypsum Co. deposits							
41	B	a	Koehn Lake deposit (1910-1913, 1922, 1923, 1926[1])	J. E. and A. D. Daly, Box 1017, Lancaster	28	30S	38E	MD	Koehn Lake	Herein; Hess 10a: 417, 418
42	D	a	Lost Hills deposit (see also Lost Hills mine)		30	26S	21E	MD	Lost Hills	Hess 20: 65, 66
43	A	a	Lost Hills mine (1934[1])	H. M. Holloway, Inc.,[2] Box 310, Lost Hills	3, 10, 11, 14, 15, 23, 24, 25, 26	26S	20E	MD	Lost Hills	Herein
44	D	a	McClure Valley deposits		S½	25S	19E	MD	McClure Valley	Hess 20: 64, 65
45	B	a	McKittrick deposit (1902, 1903, 1907-1912, 1948, 1949)	McKittrick Agricultural Gypsum Co.[2]	21	30S	22E	MD	McKittrick	Herein
46	B	a	Pacific Gypsum Co. deposit (1946[1])	Pacific Gypsum Co.,[2] Box 563, Bakersfield	26	32S	27E	MD	Kern Lake	Herein
47	B(?)	a	Packwood Canyon deposit (1948[1])	C. L. Fannin[2]	9	27S	18E	MD	Packwood Canyon	Herein
48	B	a	Telephone Hills deposits (1907-1914, 1921, 1940-1942, 1947-1950)	Mr. Rankin, Bakersfield	30, 31, 32	30S	22E	MD	McKittrick	Herein
					5	31S	22E	MD		
49	D	a	Sunset deposit		18	11N	23W	SB	Pioneer	Hess 20: 70
				Kings County						
50	B	a	Avenal Gap mine	H. M. Holloway, Inc.,[2] Box 310, Lost Hills	2, 3, 11	24S	18E	MD	Kettleman Plain	Herein

			Boyd deposit: see Dudley deposit							
51	C	a	Dudley deposit (Boyd deposit, E. B. Jones mine) (1896, 1900, 1909-1915)		13	24S	18E	MD	Kettleman Plain	Hess 20: 73-75
			E. B. Jones mine: see Dudley deposit							
52	D	a	Tulare Lake View group	Couch, Stevens, et al.[2]	26, 35, 36	21S	17E	MD	Kettleman Hills	Bradley 16:527
				Los Angeles County						
53	C	d(?)	Charlie Canyon deposit (1904, 1905)	Fire Pulp Plaster Co.[2]	10	5N	16W	SB	Charlie Canyon	Hess 20: 75
55	D	e	Mint Canyon deposit		29	5N	14W	SB	Mint Canyon	Herein
56	B	a(e)	Palmdale deposits (1892-1909)	Alpine Plaster Co.,[2] Fire Pulp Plaster Co.[2]	34, 35	6N	12W	SB	Palmdale	Herein; Hess 20: 75-77 Simpson 34: 412
				Merced County						
58	D	f(?)	Los Banos Creek deposit		32 5	10S 11S	10E 10E	MD MD	Los Banos Creek	Watts 90: 331
59	C	a	Ortigalita Creek deposit	Agricultural Minerals and Fertilizer Co., Box 832, Los Banos[2]	2	12S	10E	MD	Ortigalita Creek	Herein
				Orange County						
60	D	d	Gypsum Canyon deposit		27	4S	7W	SB (proj.)	Gypsum Canyon	Hess 20:77
61	D	d	Sycamore Canyon deposit		12	4S	8W	SB	Sycamore Canyon	Bowers 90:408
				Riverside County						
62	C	a	Barth deposit (1909, 1914, 1917)	W. C. Barth	2	4S	7W	SB (proj.)	Corona	Merrill 19:579
			Brown mine: see Midland deposits							
63	C	a	Eagle Canyon deposit (1913-1917, 1944?)	T. A. Frazer	13, 24	4S	7W	SB	Corona	Tucker and Sampson 45:168

TABULATED LIST OF CALIFORNIA GYPSUM DEPOSITS—Continued

Map No.	Class—production	Class—geological	Name (date of production)	Owner or operator	Location: Sec.	T.	R.	B&M	District	References
64	B	e	Garbutt and Orcutt deposit (1947-1950)	W. W. Orcutt estate, c.o W. K. Young, 810 S. Spring St., Los Angeles	2, 10 11	4S	20E	SB	Little Maria Mountains	Herein
			Garland deposit: see Midland deposits							
65	C	a	Gypsum (Main Street) Canyon deposit (Before 1901, 1902, 1914-1919, 1929, 1933, 1935)	J. C. Middlesworth	14, 15	4S	7W	SB (proj.)	Corona	Herein
66	C	a	Hagadore Canyon deposit (1915, 1916, 1924, 1926-1934)	J. C. Middlesworth and G. E. McCorkhill	15, 16	4S	7W	SB (proj.)	Corona	Herein
67	C	a	Jameson deposit (1915)	Jameson & Co.[2]	3	4S	7W	SB (proj.)	Corona	Merrill 19:579
			Main Street Canyon deposit: see Gypsum Canyon deposit							
			Langdon and McIntyre: see Midland deposits							
68	A	e	Midland deposits (includes Brown mine, Garland deposit, Langdon & McIntyre Savage deposit, Skelenger mine, Victor mine) (1925[1])	United States Gypsum Co. 300 W. Adams St., Chicago 6, Illinois	35, 36	3S	20E	SB	Little Maria and Maria Mountains	Herein; Tucker and Sampson 45:170-172
					1, 2, 11, 12	4S	20E	SB		
					5, 6, 7, 8, 12	4S	21E	SB		
					12, 18	4S	22E	SB		
69	D	e	Palen Mountains deposit	John Webb and Fleetwood Lawton	2, 3, 4, 9, 10, 11	3S	18E	SB	Palen Mountains	Herein; Harder 10:407-416

			Parkford deposit: see Riverside Mountains deposit							
70	D	e	Riverside Mountains deposit	Colorado Indian Reservations, Parker, Arizona	7	2S	24E	SB	Riverside Mountains	Herein; Noble 31:49-55
			Savage deposit: see Midland deposits							
			Skelenger mine: see Midland deposits							
			Standard Gypsum claims: see Garbutt & Orcutt deposit							
71	D	e	Turner deposit	Rodney Turner and Associates	6	2S	24E	SB	Riverside Mountains	Herein
			Victor mine: see Midland deposits							
72	D	a(?)	Ware deposit	H. S. Ware	9	4S	7W	SB (proj.)	Corona	
				San Benito County						
73	C	d	Alvarez & Tully deposit (before 1904)	F. O. Alvarez and J. C. Tully[2]	32 5	18S 19S	10E 10E	MD MD	Bitterwater Valley	B38:286, 287
74	D	d	Chambers deposit	Mrs. S. Chambers (before 1904)[2]	15	18S	MD	--------	Bitterwater Valley	B38:287
75	B	e	Dunne Quarries (1908-1914)[5]	-----------------------	8, 17	18S	9E	MD (proj.)	Bitterwater	Bradley et al 19:639
76	B	e	Mule Shoe Ranch deposit (1894-1899, 1908-1914, 1939, 1940, 1942, 1945, 1946)	Tannehill Cattle Co.	17, 18	18S	9E	MD (proj.)	Bitterwater	Herein
77	D	?	Silver Creek deposit	---- -------------------	NW. part	17S	12E	MD	Silver Creek	B38:287
78	D	d	Tully deposit	R. R. Tully (before 1904)[2]	11	18S	10E	MD	Bitterwater Valley	B38:287

TABULATED LIST OF CALIFORNIA GYPSUM DEPOSITS—Continued

Map No.	Class—production	Class—geological	Name (date of production)	Owner or operator	Location				District	References
					Sec.	T.	R.	B&M		
				San Bernardino County						
79	D	c	Avawatz Mountains deposits	Avawatz Salt and Gypsum Co., H. H. Kerckhoff Jr., Pres., 2545 Raleigh Dr., San Marino 9	24	18N	4E	SB	Avawatz Mountains	Herein
					15, 16, 19, 20, 21, 22, 25, 26, 27, 28, 35, 36	18N	5E	SB		
					1, 2	17N	5E	SB		
					5, 6 8	17N	6E	SB		
80	D	b	Bolo deposit	Bolo Gypsum Co. (1935)	13, 24	5N	12E	SB	Bristol Lake	
					19, 30, 31	5N	13E	SB		
81	A	b	Bristol Lake deposit	United States Gypsum Co. 300 W. Adams St., Chicago 6, Illinois	3, 10, 19, 30	5N	.12E	SB	Bristol Lake	Herein
82	D	c	Calico Mountains deposit	Mulcahy et al (1916)	27	10N	1E	SB	Calico Mountains	Storms 92:345-348; Cloudman et al 19:870
83	D	c	Camp Cady deposit		N. part	10N	4E	SB	Field	B38:287
84	D	?	Couchman deposit	J. Couchman	?	18N	9E	SB (proj.)	Coyote Holes	Tucker & Sampson 43:516
85	D	b	Danby Lake deposit		1	1N	18E	SB	Danby Lake	B38:287; herein
86	D	c	Owl Hole Spring deposit		?	18N	3E	SB	Owl Hole Spring	Herein
87	D	e	Shire deposit	D. H. Shire, 323 W. Florence, Ave., Los Angeles 3	5	17N	14E	SB	Clark Mountains	Herein

				San Diego County						
88	D	f(?)	Carrizo Creek deposit		?	15S	8E	SB	Carrizo Creek	Merrill 16:688
89	D	c	Kipp deposit	Sylvester Kipp	25	13S	8E	SB	Fish Creek Mountains	Herein; Tucker & Reed 39:44
90	D	c	National Gypsum Co. deposit	National Gypsum Co., 325 Delaware Ave., Buffalo 2, New York	3, 5, 9	13S	8E	SB	Fish Creek Mountains	Herein
91	D	c	Roberts and Peeler deposit[3]	Roberts et al., c/o. M. N. Roberts, 291 S. Marengo Ave., Pasadena	13	13S	8E	SB	Fish Creek Mountains	Herein
				San Joaquin County						
92	D	f	Vernalis deposit		?	2S	6E	MD	Vernalis	Laizure 25:191
				San Luis Obispo County						
93	D	d	Alamo Creek deposits		?	12N	32W	SB (proj.)	Alamo Creek	R94:325
94	D	d	Arroyo Grande Creek deposit		?	32S	13E	MD	Arroyo Grande Creek	Franke 35:423
95	B	a	Carrisa mine (1947[1])	V. C. Hatley and C. L. Fannin[2]	21	30S	20E	MD	Carrizo Plain	Herein
96	D	a	Carrizo Plain deposits (see also Carrisa mine)		16 to 36	31S 32S	21E 22E	MD MD	Carrizo Plain	Hess 20:83
97	B	a	Shandon deposit (1947[1])	Shandon Gypsum Co., Box 135, Shandon	21	26S	15E	MD	Shandon	Herein
				Santa Barbara County						
			Cuyama River deposit: See Cuyama River claim, Ventura County							
99	C	d	Point Sal mine (1880-1889)	John Lucas and Co.[2]	2	9N	36W	SB	Point Sal	R88:538; Hobson 90:601; Fairbanks 02:15-17
100	C	d	Santa Barbara Canyon deposit (1948)	Lew Curyea, Ventucopa	34, 35	9N	25W	SB	Santa Barbara Canyon	Herein
101	D	d	Seeley deposit	C. S. Seeley	7, 8	8N	24W	SB	Cuyama Valley	Herein
102	D	d	Wagon Road Canyon deposit	Harry Black, Merl Black, Gene Stutz	36 1	9N 8N	25W 24W	SB SB	Cuyama Valley	Herein

TABULATED LIST OF CALIFORNIA GYPSUM DEPOSITS—Continued

Map No.	Class—production	Class—geological	Name (date of production)	Owner or operator	Location Sec.	Location T.	Location R.	Location B&M	District	References
				Ventura County						
103	D	e	Ballinger Canyon deposit	Blue Diamond Corp., 1650 S. Alameda St., Los Angeles 54	10, 11 13, 14	9N	24W	SB	Cuyama Valley	Herein
104	D	d	Burges Canyon deposit	Harry Black, Merl Black, Gene Stutz	15	8N	24W	SB	Cuyama Valley	Herein
105	C	d	Cuyama River claim (includes Frenchman's Point deposit and Cuyama River deposit, Santa Barbara County) (1947)	Harry Black, Merl Black, Gene Stutz	16, 17 18	8N	24W	SB	Cuyama Valley	Herein
106	B	a	Fillmore deposit (1911-1914)	Sunset Plaster and Cement Co.	7	3N	19W	SB	Oak Ridge	Herein
			Frenchman's Point deposit: see Cuyama River claim							
107	D	e	Mathews deposit	Walt Mathews	29, 30	9N	23W	SB	Cuyama Valley	Herein
108	C	d	Ojai Gypsum mine (1890)[4]	Tacoma Calcium Co.[2]	3, 10	4N	22W	SB	Nordhoff	Bowers 88:688; Bradley et al 19:761
109	A	c	Quatal Canyon quarry (1941[1])	Monolith Portland Cement Co., 3326 San Fernando Rd., Los Angeles 65	18, 19 24	9N 9N	23W 24W	SB SB	Cuyama Valley	Herein
110	D	f	Russell Borax mine		14	8N	21W	SB	Seymour Creek	Gale 11:446,[5]447
111	D	a(?)	South Mountain deposit		24 18, 20	3N 3N	21W 20W	SB (proj.) SB (proj.)	South Mountains	Hess 20:85

[1] Indicates production continuous to date of survey, 1950.
[2] Operator.
[3] Produced celestite in 1916 and 1940-46.
[4] Location marked on state geologic map of 1891.
[5] Apparently not identical with Mule Shoe Ranch deposit.

TABULATED LIST OF PRODUCERS AND OWNERS

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
41	G. W. Abel, Mojave Desert gypsum deposit	Koehn Lake	1926-1928 (?)	Agricultural gypsum. Deposit leased from C. A. Koehn	Tucker 29:69
48	Abbott and Hickox	Telephone Hills	Pre 1907-1909	Became McKittrick Gypsum Co.	Hess 20:68
31	Acme Cement (and) Plaster Co., St. Louis, Missouri	China Ranch	1916, 1917	Class B producer; present owner, Certain-teed Products Corp.	R21:292
	Acme Cement (and) Plaster Co., St. Louis, Missouri	Los Angeles	Pre 1909- ?	Calcining plant; gypsum from China Ranch and Arizona	
55	Acme Cement (and) Plaster Co., St. Louis, Missouri	Palmdale	1910	Bought Fire Pulp Plaster Co. property; no production	
69	H. R. Adams and T. A. Blakely	Palen Mountains	1904	No production	B38:286
9	Agricultural Minerals and Fertilizer Co., A. D. Sousa, Box 832, Los Banos	Little Panoche Placer	1946[1]	Gypsite producer	Herein
59	Agricultural Minerals and Fertilizer Co., A. D. Sousa, Box 832, Los Banos	Ortigalita Creek	1949[1]	Gypsite; development in 1949	Herein
23	W. H. Allen	Tract 70, Fish Creek Mountains	1908	80 acres patented 1908. Now U. S. Gypsum property	Merrill 16:739
41	Alpine Lime and Plaster Co.	Koehn Lake	1922, 1923	Leased Koehn Lake deposit from C. A. Koehn. A small production	
	Alpine Plaster Co.	Los Angeles	1892-1901	Calcining plant; gypsum from Palmdale. Plant moved to Palmdale in 1901	R93:324
56	Alpine Plaster Co.	Palmdale	1892-1909	Class B producer. Sold to New Alpine Gypsum Co. in 1926	B38:284-286
73	F. O. Alvarez and J. C. Tully	Bitterwater Valley	Before 1904	Very small production from surface boulders	B38:286, 287

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
64	American Gypsum Co., 1140 H St., Fresno 1	Garbutt and Orcutt property	1947-1950	Agricultural gypsum, class B producer. Leased from W. W. Orcutt estate and worked by Utah Construction Co. who acquired an interest in the operation in 1948	Herein
66	Amestoy Estate	Hagador Canyon, Corona	1924, 1926-1934	Leased to E. R. Nonhoff. Abandoned and relocated by J. C. Middlesworth and G. E. McCorkill in 1941	Tucker and Sampson 45:168, 169
63	Amestoy Mineral Fertilizer Co.	Eagle Canyon, Corona	1913	Became Natural Fertilizer Co., in 1914	
79	Avawatz Salt and Gypsum Co., H. H. Kerchoff, Jr. Pres., 2545 Raleigh Drive, San Marino 9	Avawatz Mountains	1910 -1920	Owner, (?); extensive development. 1947 leased to P. J. Barnes, 1948 leased to Western Atlas Corp.	Herein
6	The Bahr Gypsum mine, 319 Cornell St., Fresno	Tumey Gulch	1947, 1948	Gypsite. Leased from H. H. Welsh estate	Herein
79	Phillip J. Barnes and associates	Avawatz Mountains	1947	Lessee; no production	Herein
62	W. C. Barth	Corona	1914, 1917	Property bought from H. A. Prizer	
2	J. H. Beaulieu	Lone Oak Gypsum mine South Riverside	1895	Agricultural gypsum used on orange groves. Small production	
102	Harry Black, Merl Black, Gene Stutz	Wagon Road Canyon deposit	1950	Under option to Maricopa Gypsum Co.	Herein
104	Harry Black, Merl Black, Gene Stutz	Burges Canyon deposit	1950	Under option to Maricopa Gypsum Co.	Herein
105	Harry Black, Merl Black, Gene Stutz	Cuyama River claim	1950	Under option to Maricopa Gypsum Co. Development and small production (?) before 1950	Herein
18	F. L. Blanc	Fish Creek Mountains	Before 1926	Patented claims, undeveloped	Tucker 26:275
103	Blue Diamond Corp., 1650 S. Alameda St., Los Angeles 54	Ballinger Canyon	?	Development only	Herein

25	Blue Diamond Corp., 1650 S. Alameda St., Los Angeles 54	Tract 71, Fish Creek Mountains	?	Development only. Belonged to E. H. Houck in 1924	Herein
	Blue Diamond Corp., 1650 S. Alameda St., Los Angeles 54	Los Angeles	1925 (?)-1941	Calcining plant; gypsum from Arden, Nevada. Moved to Arden in 1941	Holmes 50:4
	Bollinger	See Prizer, Crane and Bollinger			
81	Bolo Gypsum Co.	Bristol Lake	1935	No production	
51	C. E. Boyd	Dudley deposit	1909-1915	Acquired or leased from M. Dickson, McKittrick	Bradley 16:527
51	Buckeye Oil and Development Co.	Dudley deposit	1899 or before to 1904	No production; sold to M. Dickson, McKittrick	
19	California Gypsum Corp.	Fish Creek Mountains	1922	Development only. Claims surrendered 1927. Plans reported may have been confused with Imperial Oil and Gypsum Co.	Newman 22:419; Tucker 23:154
45	California Gypsum and Mineral Co.	McKittrick deposit	1902, 1903, 1907-1912	Gypsite	Hess 20:67, 68; Tucker 19:917
41	California Gypsum Hollow Tile Co.	Koehn Lake	1913	Plaster manufacturer affiliated with Gypsum Mining Co. Absorbed Crown Plaster Co. 1913. Bankrupt Dec. 31, 1913	
25	California Portland Cement Co., 612 S. Flower St., Los Angeles 14	Tract 67, Fish Creek Mountains	? [1]	Development only	Herein
74	Mrs. S. Chambers	Bitterwater Valley	Before 1904	Development only	B38:287
25	B. R. Chaplin	Tract 67, Fish Creek Mountains		Claimed before 1913; under option to Pacific Portland Cement Co. 1926; owned by California Portland Cement Co. 1950	Merrill 16:739; Tucker 26:275; herein
23	David Chaplin and W. L. Gillette	Tract 78, Fish Creek Mountains	Before 1913-?	Now U. S. Gypsum Co. property	Merrill 16:739; herein
31	Certain-teed Products Corp., 120 E. Lancaster Ave., Ardmore, Pennsylvania	China Ranch deposit	? [1]	Present owner. No production	Norman and Stewart 51:222

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
7	Coalinga Gypsum and Fertilizer Co., Hall, Doverall, and Lavelle	Coalinga mine	1892-1897	Leased from San Joaquin Valley Coal Mining Co. Company dissolved in 1897	R94:323; Watts 94:63
	Collins: See Green and Collins				
2	Colomo Gypsum mines, Don M. Crist, Manager, Lebec	Valley Agricultural Gypsum Co. property	1944	Lessee. No recorded production	
70	Colorado Indian Reservation, Parker, Arizona	Riverside Mountains deposit	1929, 1930	Leased to E. A. Parkford and J. M. Wilson. Assessment work only	Tucker and Sampson 29:511
	A. A. Conrowe: See Dos Palos Gypsum Co.				
2	Consolidated Gypsum and Plaster Co.	West side, Little Maria Mountains	Between 1904 and 1915	Assessment work only	Merrill 19:579
81	Consolidated Pacific Cement Plaster Co. (Pacific Cement Plaster Co. before 1909)	Bristol Lake deposit	1906-1919	Development and production, class A producer. Sold to U. S. Gypsum Co.	Cloudman et al. 19: 869, 870; Hess 20: 81-83
	L. E. Cooley: See W. O. Hamilton and L. E. Cooley				
	Cottonwood Co.: See W. A. Fauntleroy				
52	Louis Couch, Oscar Couch, R. E. Stevens, et al.	Tulare Lake View group	Before 1914	Assessment work only	Bradley 16:527
84	J. Couchman	Coyote Holes		Undeveloped	Tucker and Sampson 30:307
	Crane: see Prizer, Crane, and Bollinger				
2	Crescent Gypsum Co; M. M. Lavelle, Mgr.	Unknown	1890 to 1900	No production recorded	
	Don M. Crist: see Colomo Gypsum mines				

41	Crown Plaster Co.	Koehn Lake	1912, 1913	Class B producer. Absorbed by California Gypsum Hollow Tile Co. in 1913	
36	Crystal Gypsum Co., Box 823, Oildale	Kern Lake	1947, 1948	Gypsite	Herein
100	Lew Curyea, Ventucopa	Santa Barbara Canyon deposit	1948	Small production	Herein
[2]	Cuyama Gypsum mine, Maricopa	Uncertain	1947	Agricultural gypsum possibly from Frenchman's point	Fert. Mat.: 1947
41	A. D. and J. E. Daly (J. E. and C. A. Koehn)	Koehn Lake	1910-1913, 1922-1923, 1926[1]	Small, intermittent production by owner or lessee	Hess 20:73; Tucker 29:69; herein
40	De Barte and Bohns	Jim's Gypsum mine	1939, 1940	Gypsite, class C producer	
50	M. Dickson, McKittrick	Dudley deposit	1904-1909 (?)	No production by Dickson, bought from Buckeye Oil and Development Co., sold or leased to C. E. Boyd	
22	Mrs. Anna Dillon	Coyote Mountain Sulfur and Gypsum Deposit		Leased to Vesubio Mining Corp.	Sampson and Tucker 42: 143, 144
	O. L. Divens and A. A. Conrowe: See Dos Palos Gypsum Co.				
17	Dos Palos Gypsum Co. (O. L. Divens and A. A. Conrowe)	Snow King deposit, Panoche Hills	1939-1941	Gypsite, class C producer. Valley View mine, R. P. Jones now in the same general location	
76	J. F. Dunne (Dunn)	Mule Shoe Ranch deposit	1894-1899, 1908-1914	Owner, leased to several operators	Laizure 26:236; Bradley et al. 19:639; Boalich 22:218
	Doverall: See Coalinga Gypsum and Fertilizing Co.				
75	J. F. Dunne	Dunne Quarries	1908-1914	Class B producer. Passed into control of Lyons Gypsum Co. between 1916 and 1922	Laizure 26:236; Bradley et al 19:639: Boalich 22:218
[2]	El Cerito Ranch	Corona	1915, 1917	Gypsite. Small production for private use	Merrill 19:579
14	Eureka Gypsum mines, Milton McWorter	Coalinga	1896-?	Bought San Joaquin Valley mine. Gypsum also mined at McKittrick and Cantua	Latta 49:146
47	C. L. Fannin (see also V. C. Hattey and C. L. Fannin)	Packwood Canyon deposit	1948[1]	Gypsite	Herein

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
35	W. A. Fauntleroy	Cottonwood Creek deposit	1890-1898	Small production. Leased (?) to Pampa Gypsum Co., Cottonwood Co., Gypsum Mining Co.	Angel 90:223
53	Fire Pulp Plaster Co.	Charlie Canyon deposit	1904, 1905	Abandoned; operations transferred to Palmdale	Hess 20:75
56	Fire Pulp Plaster Co.	Palmdale	1906-1910	Sold to Acme Cement and Plaster Co. No production after 1906	
100	C. D. Fox	Santa Barbara Canyon deposit	About 1904	No production reported	B38:288
63	T. A. Frazer	Eagle Canyon deposit, Corona		Owner in 1944. Leased to Levi Katz and Floyd Shoemaker	Tucker and Sampson 45:168
65	G. R. Freeman (see also G. W. Lord)	Gypsum Canyon deposit, Corona	1916-1937	Partner with G. W. Lord after 1916. Executor of Lord's estate 1918-1920. Operator of the deposit after 1920	
	Freeman: See E. R. Nonhoff and Freeman				
	F. A. Garbutt and W. W. Orcutt; see W. W. Orcutt estate				
68	Garland	Garland deposit, Maria Mountains		Assessment work only by Garland. Sold to U. S. Gypsum Co. between 1930 and 1945	Tucker and Sampson 29:510; Tucker and Sampson 45:170
23	W. F. Gillett	Fish Creek Mountains		Owner in 1926. Claim included in Regent Placer patented in 1928 by Pacific Portland Cement Co., now owned by U. S. Gypsum Co.	
	W. L. Gillette: see David Chaplin and W. L. Gillette				
48	Green and Collins	Telephone Hills, McKittrick	1941	Gypsite. Deposit 4 miles southwest of McKittrick	

15	Green and Collins	Valley View Placer, Panoche Hills	1934-1939	Gypsite, class B producer. The Super Gypsum mine is now in the same general locality	
	Harold Green: see Gypsum Products Corp.				
16	J. K. Griffin, 270 Upland Dr., San Francisco	Tumey Gulch	1947-1949	Gypsite class C producer. Trustee of H. H. Welsh, deceased	Herein.
38	Gypsum Co. of California	Telephone Hills, McKittrick	1946, 1947	Gypsite. Deposit worked out and abandoned	Herein.
	Gypsum Incorporated	Plant location, Rosamond	1946, 1947	Wallboard and plaster manufacturer. Gypsum from Koehn Lake and Maricopa. Plant in the hands of Champco Minerals in 1948	Tucker et al. 49:248
2	Gypsum Land Plaster Co., J. H. Henry and E. S. Jones, San Jose	San Benito County	1895, 1896	Gypsum perhaps from the Mule Shoe Ranch deposit	
	Gypsum Mining Co. see W. A. Fauntleroy				
	Gypsum Mining Co., Randsburg: see California Gypsum Hollow Tile Co.				
64	Gypsum Products Corp., Harold Green, San Francisco	Garbutt and Orcutt deposit	1945	Lessee. Development only. Diamond drilling carried out at this time	
	J. H. Hall: see Paoli Gypsum Co.				
	Hall, Doverall, and Lavelle: See Coalinga Gypsum and Fertilizing Co.				
23	W. O. Hamilton and L. E. Cooley	Tract 69, Fish Creek Mountains		160 acres staked before 1913. Now part of the Fish Creek Mountains mine	Merrill 16:739
39	Handel and Son (C. Handel Brothers, Handel and Richards)	Lost Hills	1941-1944	Gypsite, class B producer	
	W. J. Hammond	Panoche No. 1 and No. 2	1947 (approx.)	Gypsite	
35	William Harmon	Cottonwood Creek	Before 1907	Gypsite claims covering in part the Fauntleroy property; no Production by Harmon	Hess 20:70, 71

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
95	V. C. Hatley and C. L. Fannin	Carrisa mine	1947	Gypsite producer	Herein
	J. H. Henry and E. S. Jones: See Gypsum Land Plaster Co.				
[2]	Heffron Brothers	Corral Canyon, Cuyama Valley	1951	Undeveloped claim	Herein
	Hickox: See Abbott and Hickox				
	Hickox and Hubbard: See McKittrick Gypsum Co.				
	I. A. Himes, Peg Leg mines, Star Route 1, Barstow	Barstow	1947, 1948	Grinding and mixing plant producing agricultural gypsum. Source of gypsum not known	Fert. Mat. 1949
43	H. M. Holloway Inc.; Box 310, Lost Hills	Lost Hills mine	1934[1]	Gypsite, class A producer	Herein
50	H. M. Holloway Inc.	Avenal Gap mine	1947[1]	Gypsite	Herein
[2]	Hollowell and Roeben Bros., Visalia		1947	Gypsite producer, mine location not known	Fert. Mat. 1947
26	E. H. Houck	Tract 71, Fish Creek Mountains		40 acres claimed before 1913. Now owned by Blue Diamond Corp.	Merrill 16:739; Tucker 26:275
	W. F. Hubbard: See McKittrick Gypsum Co.				
23	Imperial Gypsum Co. (Imperial Gypsum and Oil Co. in 1924)	Fish Creek Mountains mine	1922-1924	Development and production. Sold to Pacific Portland Cement Co.	Newman 22:232; Newman 23:31; Bradley 25:261
[2]	Imperial Valley Gypsum Co.	Coyote Mountains	1915	Plans for development	
67	Jameson & Co.	Corona	1915	Small production of gypsite for private use	
51	E. B. (E. D.) Jones	Dudley deposit	1896, 1900	Leased from Buckeye Oil and Development Co.	R96:503

	E. S. Jones: See Gypsum Land Plaster Co.				
17	R. P. Jones, Valley View mine, Box 221, Madera	Panoche Hills	1948[1]	Gypsite. On ground previously worked by Dos Palos Gypsum Co.	
54	Kaiser Gypsum Div., Kaiser Industries, Inc. Kaiser Building, Oakland 12	Long Beach plant	1944[1]	Producer of plaster and board products. Gypsum from San Marcos Island. Purchased from Paraffine Companies. Called Standard Gypsum Co. of California before 1950	Utley 47
98	Kaiser Gypsum Div., Kaiser Industries, Inc. Kaiser Building, Oakland 12	Redwood City plant	1949[1]	Producer of board products. Gypsum from San Marcos Island. Purchased from Pacific Portland Cement Co. late in 1949	Herein
63	Levi Katz and Floyd Shoemaker	Eagle Canyon deposit, Corona	1944	Lessee. Development and possibly a small production	Tucker and Sampson 45:168
	H. H. Kerckhoff Jr., see Avawatz Salt and Gypsum Co.				
[2]	Kern County, Gypsite Co.	McKittrick	1921, 1922	Small production reported. Deposit bought from La Corona Oil and Asphalt Co.	
89	Sylvester Kipp	Fish Creek Mountains	?[1]	Undeveloped claims	Tucker and Reed 39:44
	J. E. and C. A. Koehn: See J. E. and A. D. Daly				
[2]	La Corona Oil and Asphalt Co.	McKittrick	1908-1913	Production of gypsite. Sold to Kern County Gypsite Co. in 1921	
68	C. M. Langdon and P. D. McIntyre	Maria Mountains		Undeveloped. Sold to U. S. Gypsum Co. between 1929 and 1945	Tucker and Sampson 29:510, Tucker and Sampson 45:170
109	A. H. Lange	Quatal Canyon quarry	1941	Contractor for Monolith Portland Cement Co. Development and production	
	Lavelle: See Coalinga Gypsum and Fertilizing Co.				
69	Fleetwood Lawton, 534 Muirfield Road, Los Angeles 5	Palen Mountains deposit	1949	Partner with John Webb	

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
8	J. C. Lillis	Tumey Gulch	?	Owns mineral rights on parts of the Welsh property, including part of the Paoli mine	Herein
65	G. W. Lord (see also G. R. Freeman)	Gypsum Canyon deposit, Corona	1906-1917	Small intermittent production. Partner with G. R. Freeman after 1915	
	John Lucas and Co.	Golden Gate Plaster Mill, San Francisco	1875-1900	Gypsum from San Marcos Island, Point Sal mine, and probably other California deposits. Burned in 1900	Santmyers 29:7; R84:227
99	John Lucas and Co.	Point Sal mine	1880-1889	The earliest gypsum mining in California of which there is a definite record	R84:227, R88:538
[2]	S. Lyons and Dunn Brothers	Bitterwater Valley	1896 and earlier	Production reported. The relation to Dunne Quarries and Lyons Gypsum Co. is not clear	R96:504
75	Lyons Gypsum Co., T. W. G. Lyons	Dunne Quarries	After 1916	Bought from J. F. Dunne. No production by Lyons	
76	Lyons Gypsum Co., T. W. G. Lyons	Mule Shoe Ranch	Before 1926	Leased from J. F. Dunne	Laizure 26:236
27	S. C. Mack	Tract 72, Fish Creek Mountains		40 Acres claimed before 1913. Owned by I. M. Wilson in 1951	Merrill 16:739
	Maricopa Gypsum Co., Box 361, Maricopa	Cuyama Valley	1950	Options to lease Black and Seeley claims	Herein
	P. D. McIntyre: see C. M. Langdon and P. D. McIntyre				
45	McKittrick Agricultural Gypsum Co.	McKittrick deposit	1948-1950	Gypsite producer, class B. Both operations abandoned	Herein
48	McKittrick Agricultural Gypsum Co.	Telephone Hills	1948-1950		
[2]	McKittrick Extension Oil Co.	McKittrick	1915	Production of gypsum reported	

48	McKittrick Gypsum Co., Hickox and W. F. Hubbard	Telephone Hills	1909-1914	Gypsite producer, class C. Abbott and Hickox before 1909	
	Milton McWorter: see Eureka Gypsum mines				
65	J. C. Middlesworth	Gypsum Canyon deposit, Corona	1941 (?)	Owner in 1945. Leased to Victor Mishelle. No production	Tucker and Sampson 45:168
66	J. C. Middlesworth and G. E. McCorkhill	Hagador Canyon deposit, Corona	1941	Formerly Amestoy Estate property. Relocated by present owners in 1941. Leased to Victor Mishelle. No production	Tucker and Sampson 45:168, 169
63	Mineral Fertilizer Co.	Eagle Canyon deposit, Corona	1916, 1917	Natural Fertilizer Co., before 1916. No production reported after 1917	
	Victor Mishelle: see J. C. Middlesworth, J. C. Middlesworth and G. E. McCorkhill				
	Mojave Desert Gypsum Deposit: see G. W. Abel				
48	Monolith Portland Cement Co., 3326 San Fernando Rd., Los Angeles 65	Telephone Hills, McKittrick	1940, 1941	For Portland cement retarder. Worked out and abandoned	Tucker et al. 49:248
109	Monolith Portland Cement Co., 3326 San Fernando Rd., Los Angeles 65	Quatal Canyon quarry	1942[1]	For Portland cement retarder. See also A. H. Lange	Herein
76	Monterey Gypsum Co.	Mule Shoe Ranch deposit	1945, 1946	Lessee. Produced high grade ground agricultural gypsum	Averill 47:51
	Joe Montgomery and associates: see Standard Gypsum Co., Los Angeles			Property abandoned and equipment dismantled	
82	M. Mulcahy et al.	Calico Mountains deposit	1916	Undeveloped claims	Cloudman et al. 19:870
90	National Gypsum Co., 325 Delaware Ave., Buffalo 2, New York	Fish Creek Mountains	1948, 1949	Claims filed and plans for development announced. Plans abandoned	Rock Products 48, no. 5, p. 67
63	Natural Fertilizer Co.	Eagle Canyon deposit	1914, 1915	Agricultural gypsum. Amestoy Mineral Fertilizer Co. before 1914. Mineral Fertilizer Co. after 1915.	
56	New Alpine Co.	Palmdale	1926	Took over the assets of the Alpine Plaster Co. No production reported	Tucker 27:327

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
66	E. R. Nonhoff	Hagador Canyon deposit, Corona	1924, 1926-1933	Leased the deposit from Amestoy Estate	Tucker and Sampson 45:169
66	E. R. Nonhoff and Freeman	Hagador Canyon deposit, Corona	1934	No production reported after 1934	
[2]	Freeman Nonhoff	Corona	1923	Small production reported	
64	W. W. Orcutt Estate	Garbutt and Orcutt deposit	1920 (?)[1]	Deposit acquired from Standard Gypsum Co. by F. A. Garbutt and W. W. Orcutt. See also American Gypsum Co. and Gypsum Products Corp.	Herein
100	Owen Gypsum Co.	Santa Barbara Canyon deposit	About 1894	No production reported	R94:325
57	Pabco Products Inc., 475 Brannan St., San Francisco	2431 Firestone, South Gate	?[1]	Board plant, gypsum from near Las Vegas, Nev. Operated by the subsidiary, Schumaker Wall Board Co.	Herein
54	Pabco Products, Inc., 475 Brannan St., San Francisco	Long Beach	1929-1944	Calcining plant, gypsum from San Marcos Island. Operated by the subsidiary, Standard Gypsum Co. Plant and deposit sold to H. J. Kaiser	Herein
	Pacific Cement Plaster Co.: see Consolidated Pacific Cement Plaster Co.				
30	Pacific Coast Borax Div., Borax consolidated Ltd., 510 W. Sixth St., Los Angeles	Black Mountains deposit	Before 1919[1]	Undeveloped	Eakle et al. 19:87
46	Pacific Gypsum Co., Box 563, Bakersfield	Kern Lake	1946[1]	Gypsite, class B producer	Herein
23	Pacific Portland Cement Co.	Imperial Gypsum Quarry	1924-1945	Raw and calcined gypsum products. Plant at Plaster City. Bought from Imperial Gypsum and Oil Co., sold to U. S. Gypsum Co.	Bradley 25:261; Tucker 26:271-275; Sampson and Tucker 42:135, 136

98	Pacific Portland Cement Co.	Redwood City	1942-1949	Board plant. Crude gypsum bought from Kaiser and Westvaco. Plant sold to Kaiser Gypsum Div., Kaiser Industries, Inc.	Herein
2	Paoli Gypsum Co., J. H. Hall, Mgr.	Tumey Gulch	1892-1900 (?)	Small production	R94:323, 324
12	Paoli mine, A. P. Shepard	Tumey Gulch	1930-1939	Gypsite. Product reported used for agriculture and Portland cement retarder. Deposit owned in part by Shepard and in part by H. H. Welsh estate	Bradley et al. 16:452. Herein
	Pampa Gypsum Co.: see W. A. Fauntleroy				
	E. A. Parkford and J. M. Wilson: See Colorado Indian Reservation				
91	W. F. Peeler (Peler?) and D. R. Roberts	Roberts and Peeler deposit	1916	Production of celestite but not gypsum	R21:271, 272
	Peg Leg mines: See I. A. Himes				
	George Pepperdine: see John Webb and George Pepperdine				
62	Prizer, Crane, and Bollinger	Corona	1909	Small production of agricultural gypsum. Sold to W. C. Barth in 1914	
	Richards: see Handel and Son				
68	Riverside Gypsum Co., Mr. Schellenger	Little Maria Mountains	1916 or earlier	Abandoned. Ground later relocated by U. S. Gypsum Co.	Merrill 19:579
91	E. B. Roberts et al.; c/o M. N. Roberts, 291 S. Marengo Ave., Pasadena	Roberts and Peeler deposit	1940-1946	Production of celestite but not gypsum. Owners in 1942 were M. N. Roberts and O. F. Peeler	Sampson and Tucker 42:136, 143
	Roeben Brothers: see Hollowell and Roeben Brothers				
68	Ray Savage	Maria Mountains	Before 1929	Bulk sampling by Savage. Sold to U. S. Gypsum Co. between 1930 and 1945	Tucker and Sampson 29:511-513; Tucker and Sampson 45:170
	Schellenger: see Riverside Gypsum Co.				

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
[2]	Paul Schuck	Panoche Hills	1913 and earlier	Small production of gypsite. Divens and Conrowe, Green and Collins, R. P. Jones, and Super Gypsum Co. later worked in the same area	Bradley et al. 16:452
	Schumaker Wall Board Co. (see also Pabco Products, Inc.)	Los Angeles	Before 1920-?	Manufacturer of wallboard from purchased stucco	
101	C. S. Seeley	Cuyama Valley	1950	Four unpatented claims under option to Maricopa Gypsum Co.	Herein
97	Shandon Gypsum Co., Box 135, Shandon. L. L. Styles	Shandon deposit	1950-[1]	Owner and operator. Formerly leased to C. E. Vanderford	Herein
	A. P. Shepard: see Paoli mine				
87	D. H. Shire, 323 W. Florence Ave., Los Angeles 3	Shire deposit, Clark mountain area	1946-[1]	8 unpatented claims; no development	Herein
[2]	Soil Tone Co.	Corona	1915, 1916	Gypsite, class C producer. May have been from Hagador Canyon	Merrill 19:579
	A. D. Sousa: see Agricultural Minerals and Fertilizer Co.				
	Snow King: see Dos Palos Gypsum Co.				
65	Standard Fertilizer Co.	Gypsum Canyon deposit, Corona	Before 1900-1906	Production of gypsite reported 1901, 1902. Sold to G. W. Lord	
64	Standard Gypsum Co.	Garbutt and Orcutt deposit	1919, 1920	Claims patented and bulk samples sent to Los Angeles. Property acquired by F. A. Garbutt and W. W. Orcutt in 1920	
69	Standard Gypsum Co., Los Angeles, Joe Montgomery and associates	Palen Mountains deposit	1920	Plans reported to form a company and do development work	R21:326
	Standard Gypsum Co., San Francisco	Ludgwig, Nevada	1923-1929	Mine and calcining plant at Ludgwig, Nevada	Santmyers 29:21

54	Standard Gypsum Co., San Francisco (see also Pabco Products, Inc.)	Long Beach	1925-1929	Calcining plant at Long Beach; gypsum from San Marcos Island mined by a Mexican subsidiary. Plant and deposit sold to Pabco products, Inc.	Santmyers 29:7
	Standard Gypsum Co. of California: see Kaiser Gypsum Division, Kaiser Industries, Inc.				
[2]	Star Gypsum Co.	Lost Hills	1943, 1944	Gypsite, class B producer	
	R. B. Steyer: See Uneeda Gypsum Co.				
	Gene Stutz: See Harry Black, Merl Black, and Gene Stutz				
	L. L. Styles: See Shandon Gypsum Co.				
23	C. H. Swallow	Fish Creek Mountains	Before 1913	160 acres, undeveloped. Ground covered by Swallow, Placer and Swallow No. 2 Placers patented 1931 by W. H. Trenchard et al. Owned by U. S. Gypsum Co. in 1950	Merrill 16:739; herein
106	Sunset Plaster and Cement Co.	Fillmore deposit	1911-1914	Calcining plant in Fillmore	Bradley et al. 19:761
9	Super Gypsum Co., Box 66, Chowchilla	Panocho Hills	1947-1950	Gypsite producer. On ground previously worked by Green and Collins	Fert. Mat.
108	Tacoma Calcium Co.	Ojai Gypsum mine	1890	Development by shaft and drifts. No production recorded	Bradley et al. 19:761
76	Tannehill Cattle Co.	Mule Shoe Ranch deposit	?	Owner. Leased to Triangle Fertilizer Co. and Monterey Gypsum Co.	Herein
[2]	Theta Gypsum Co.	Lost Hills	1941-1943	Gypsite, class C producer	
23	W. H. Trenchard et al (see also C. H. Swallow)	Fish Creek Mountains	1931-about 1945	Swallow and Swallow No. 2 placers, patented 1931, sold to U. S. Gypsum Co.	
76	Triangle Fertilizer Co.	Mule Shoe Ranch deposit	1938-1942	Lessee. Produced high grade, ground agricultural gypsum	
78	R. R. Tully	Bitterwater Valley	Before 1904	Development only	B38:287

TABULATED LIST OF PRODUCERS AND OWNERS—Continued

Map No.	Name	Location or name of deposit	Date of activity	Remarks	References
71	Rodney Turner and Associates	Riverside Mountains	About 1945	Undeveloped. Access road started	Tucker and Sampson 45:170
[2]	Uneeda Gypsum Co., R. B. Steyer	Panoche Hills	1942	No record of production	
81	United States Gypsum Co., 300 W. Adams St., Chicago 6, Illinois	Bristol Lake	1919[1]	Deposit and calcining plant bought from Consolidated Pacific Cement Plaster Co. Last production 1924. Plant dismantled	
23	United States Gypsum Co., 300 W. Adams St., Chicago 6, Illinois	Fish Creek Mountains mine	1945[1]	Deposit and plant bought from Pacific Portland Cement Co. Manufacturer of raw and calcined gypsum products	
28	United States Gypsum Co., 300 W. Adams St., Chicago, Illinois	Plaster City plant			
68	United States Gypsum Co., 300 W. Adams St., Chicago 6, Illinois	Midland deposits	Before 1914[1]	Development and production. Production began 1925. Calcining plant completed 1928	Waring 19:577-579; Tucker and Sampson 29:513-515; Tucker and Sampson 45:170-172
64	Utah Construction Co.	Inca operation	1947-1950	Producer of high grade ground agricultural gypsum. Mined gypsum from Garbutt and Orcutt property for American Gypsum Co. Grinding plant at Inca Siding. Acquired an interest in the operation in 1948	Herein
[2]	Valley Agricultural Gypsum Co.	Belridge	1939-1943	Gypsite producer, class B	
	Valley View mine: see R. P. Jones				
	Valley View Placer: see Green and Collins				
97	C. E. Vanderford	Shandon deposit	1947-1950	Gypsite producer. Leased from L. L. Styles. Deposit worked by owner in 1951	
22	Vesubio Mining Corp., Box 592, Calexico	Coyote Mountains Sulfur and gypsum deposit	1944	Plant at Calexico producing agricultural mineral containing gypsum and sulfur. Gypsum reported mined in 1944	

	John Vils: see Western Gypsum Co.				
23	S. L. Ward	Tract 68, Fish Creek Mountains	1908-1920	120 acres patented 1908. Sold to Imperial Gypsum Co.	Merrill 16:739
72	H. S. Ware	Corona	1947	No record of production	
29	W. H. Waters	Fish Creek Mountains	About 1925	Undeveloped	Tucker 26:275
69	John Webb and George Pepperdine. (see also Fleetwood Lawton)	Palen Mountains deposit	Before 1929-[1] (?)	Development only	Tucker and Smpson 45:169, 170
10	H. H. Welsh. J. K. Griffin, Trustee	Monocline Ridge depsoit	?-[1]	Undeveloped	Herein
16	H. H. Welsh. J. K. Griffin, Trustee	Tumey Gulch deposit	?-[1]	Includes part of the land the Paoli mine was on. Mineral rights of portions of the property belong to S. C. Lillis	Herein
79	Western Atlas Corp., c/o W. W. Kaye, 417 S. Hill St., Los Angeles	Avawatz Mountains deposit	1948-1951	Lessee. No production of gypsum	Herein
[2]	Western Gypsum Co., John Vils, 733 Maple St., Wasco	Belridge	1950-[1]	Producer of gypsite	
48	Western Gypsum Co., John Vils, 733 Maple St., Wasco	Telephone Hills, McKittrick	1941, 1942, 1946-1950	Producer of gypsite. Still has the lease	
[2]	Western Petroleum Co.	McKittrick	1904	No record of production	B38:284
2	Westvaco Chemical Division, Food Machinery and Chemical Corp., 905 Lexington Ave., New York 17, N. Y.	Newark	1938-[1]	Synthetic gypsum	Seaton 42:12-15
27	Isabelle M. Wilson, R.F.D. 127, Clarksburg	Tract 72, Fish Creek Mountain	?-[1]	40 acres undeveloped. Owned by S. C Mack in 1913	
	J. M. Wilson: see E. A. Parkford and J. M. Wilson				
70	Young	Riverside Mountains deposit	After 1945	Lessee. No production	

[1] Indicates activity continuous to date of survey, 1950.
[2] Exact location of deposit not known.

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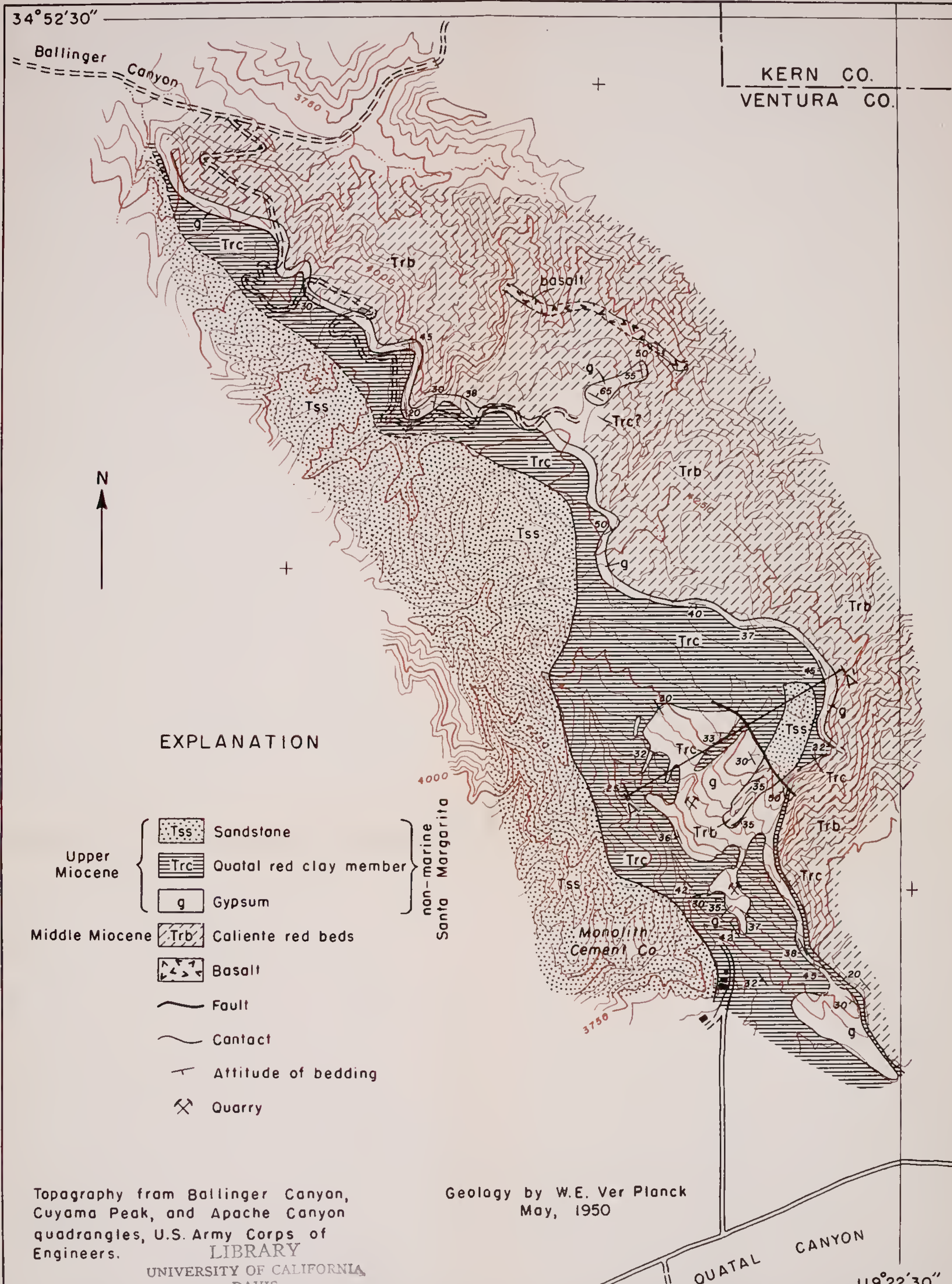
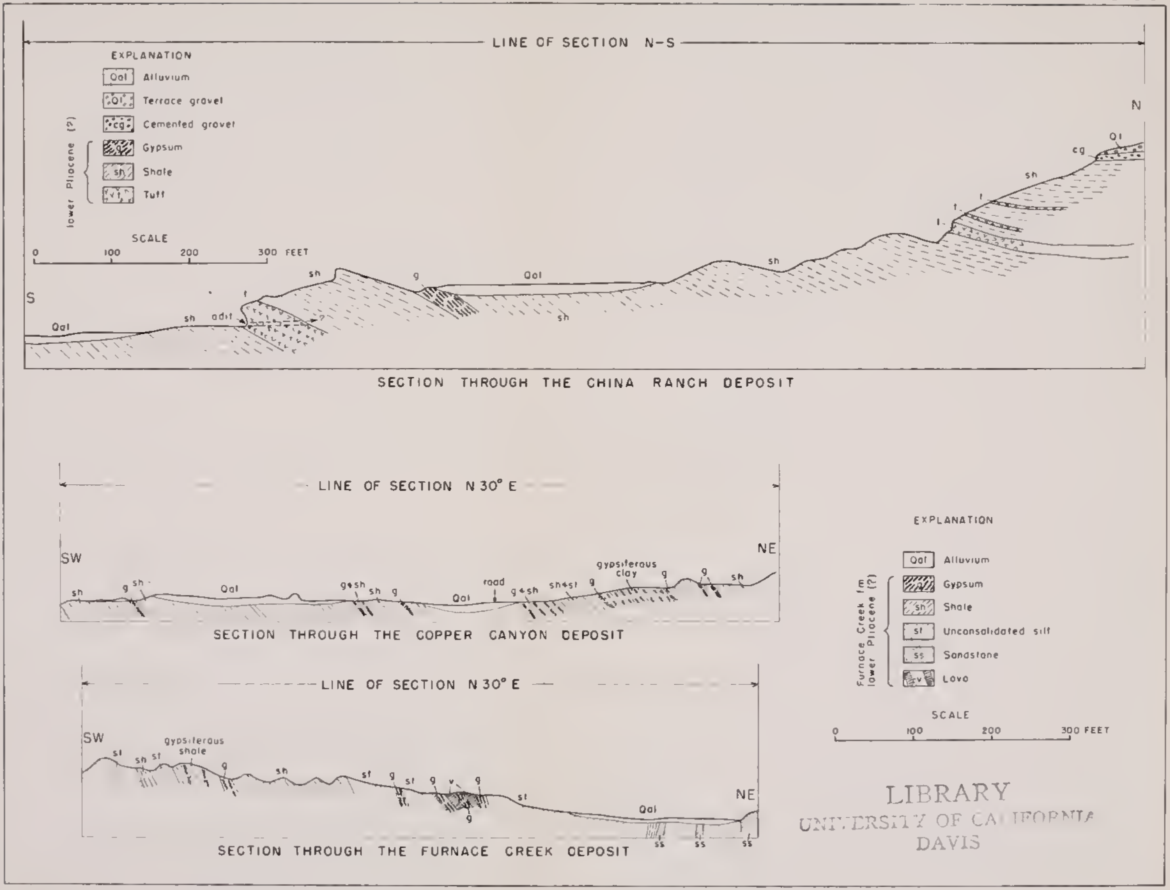


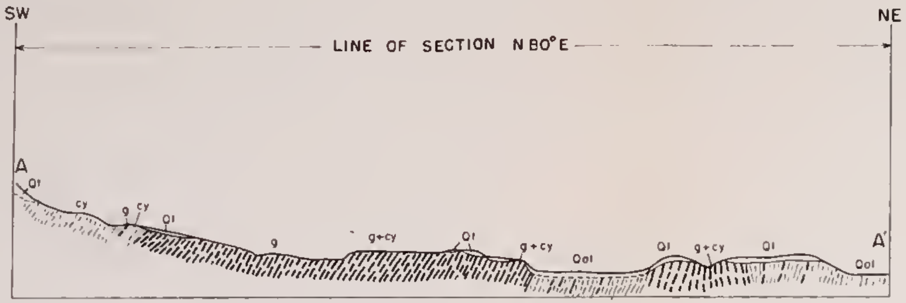
GEOLOGIC MAP OF THE QUATAL CANYON GYPSUM DEPOSIT VENTURA COUNTY, CALIFORNIA

0 1/2 1 Mile

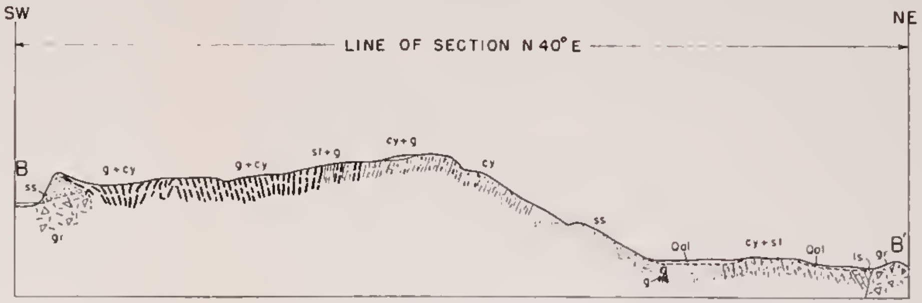
Contour interval 50 feet



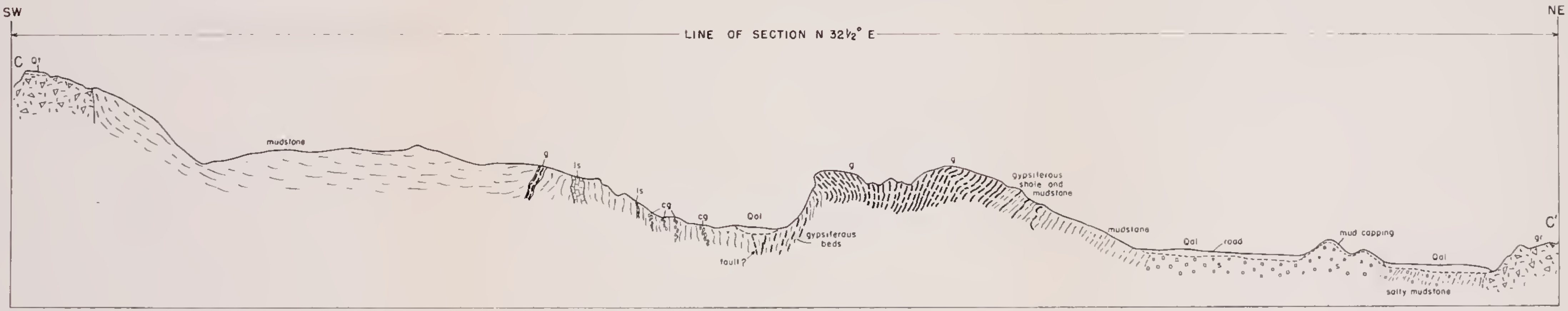
GEOLOGIC SECTIONS ACROSS THREE GYPSUM DEPOSITS – INYO COUNTY, CALIFORNIA



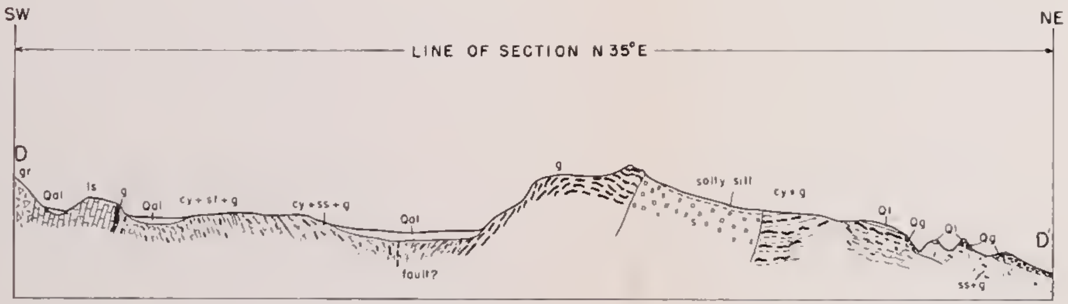
SECTION A–A' THROUGH "WEST END" DEPOSIT



SECTION B–B' KELLEY OR BIG GYPSUM HILL DEPOSIT



SECTION C–C' THROUGH SALT BASIN



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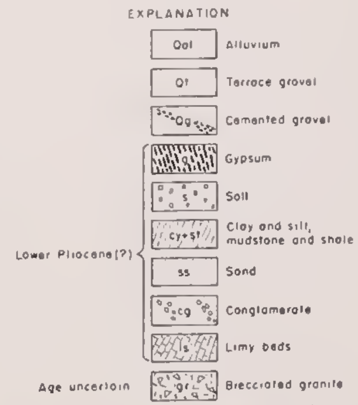
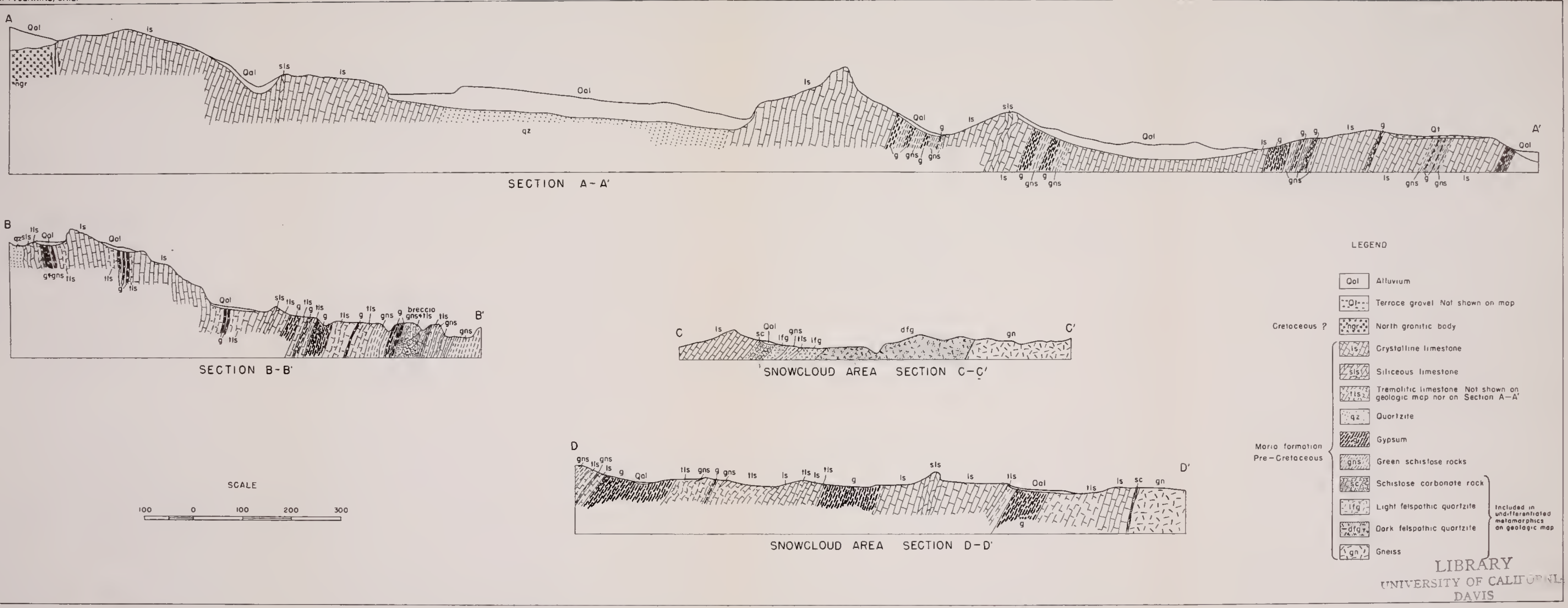
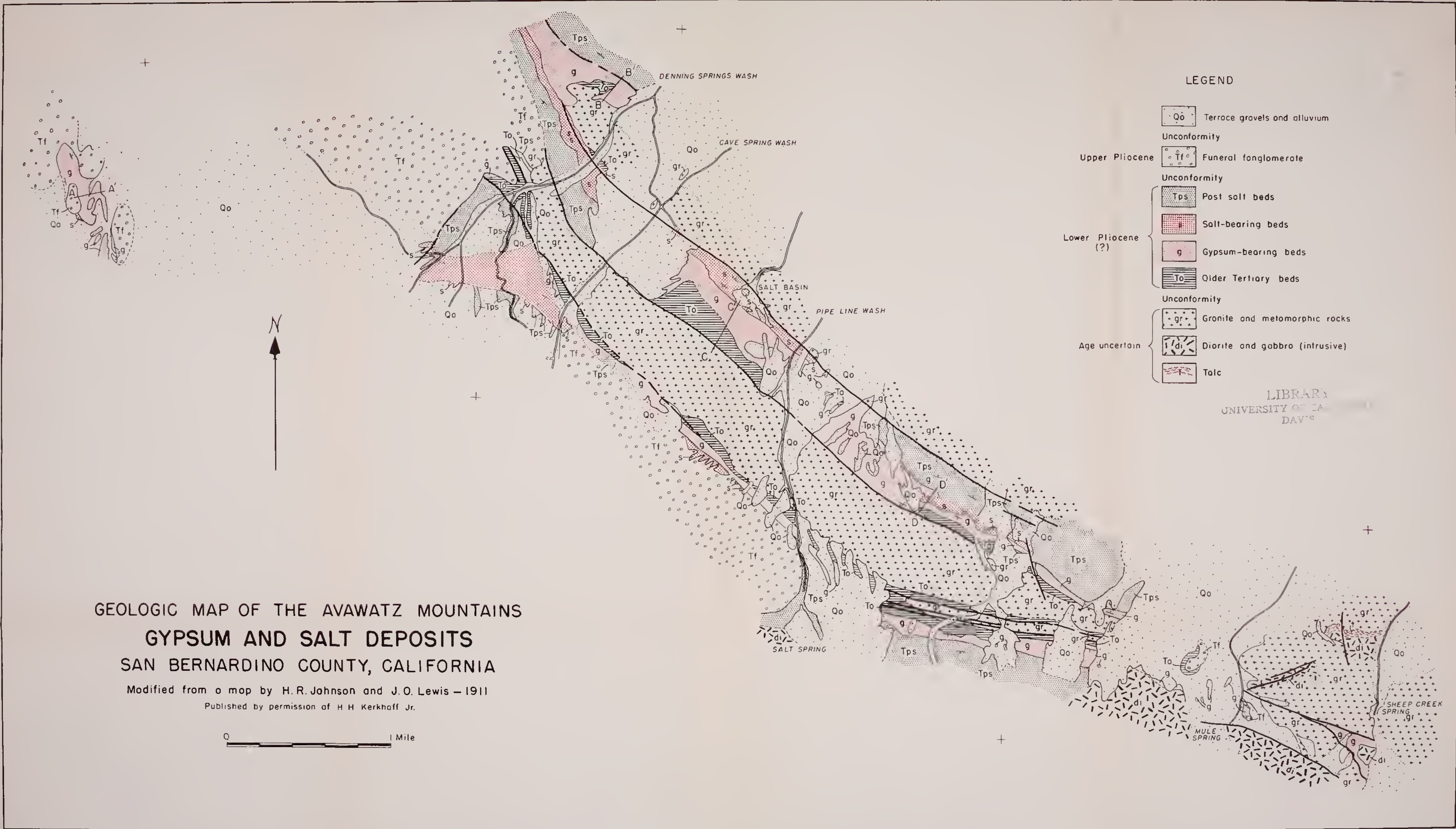


GEOLOGIC SECTIONS ACROSS THE AVAWATZ MOUNTAINS SALT AND GYPSUM DEPOSITS



STRUCTURE SECTIONS THROUGH THE LITTLE MARIA MOUNTAINS GYPSUM DEPOSITS



GEOLOGIC MAP OF THE AVAWATZ MOUNTAINS

GYPSUM AND SALT DEPOSITS

SAN BERNARDINO COUNTY, CALIFORNIA

Modified from a map by H. R. Johnson and J. O. Lewis – 1911

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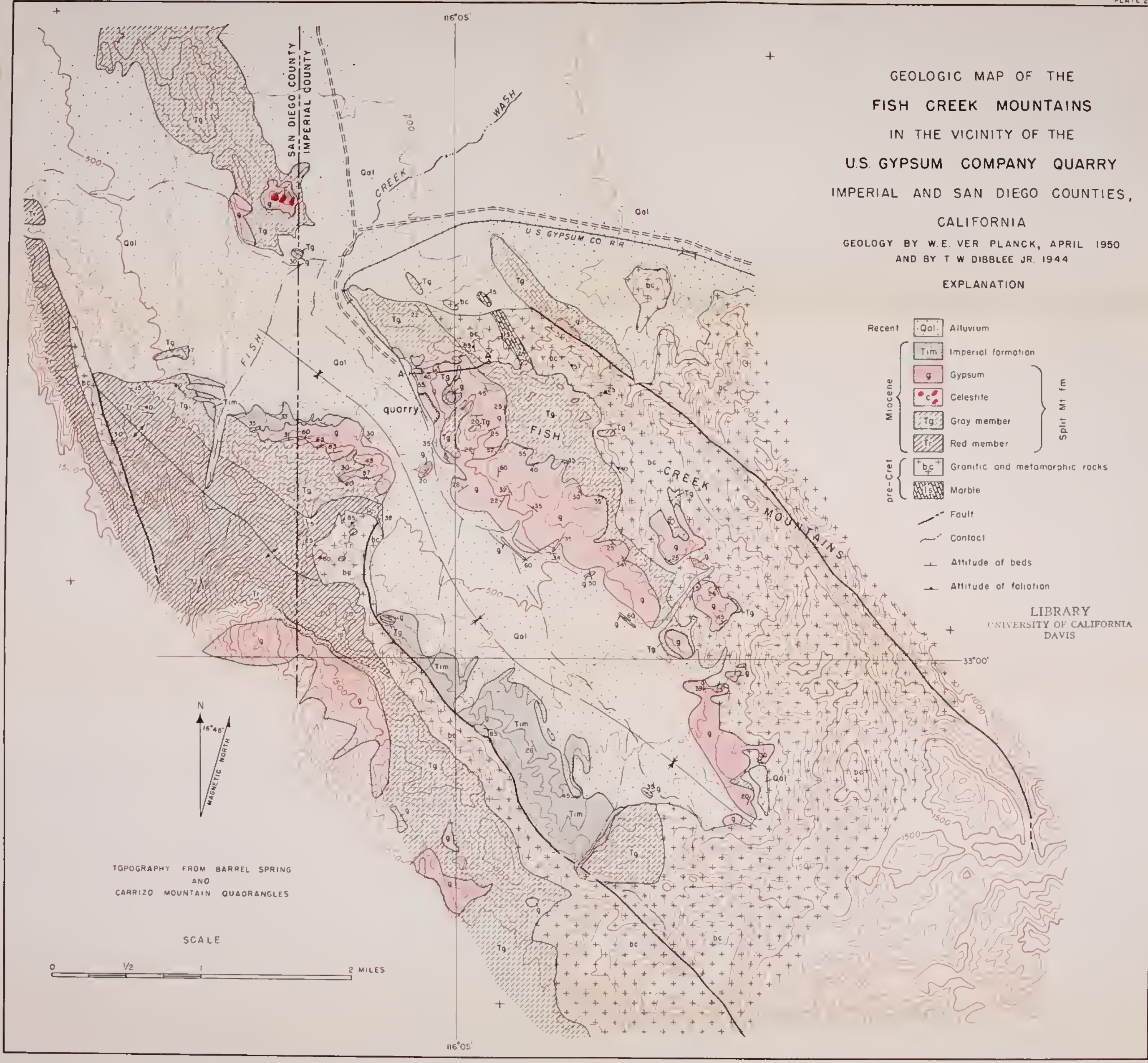
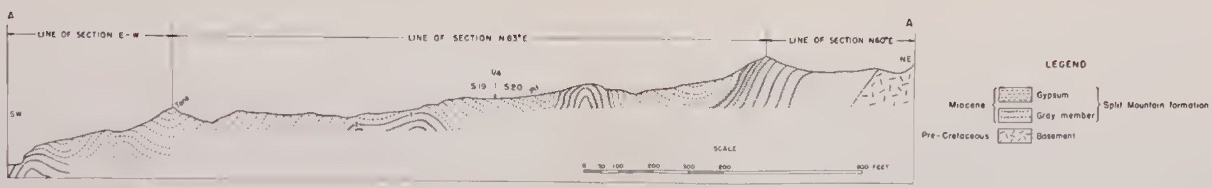
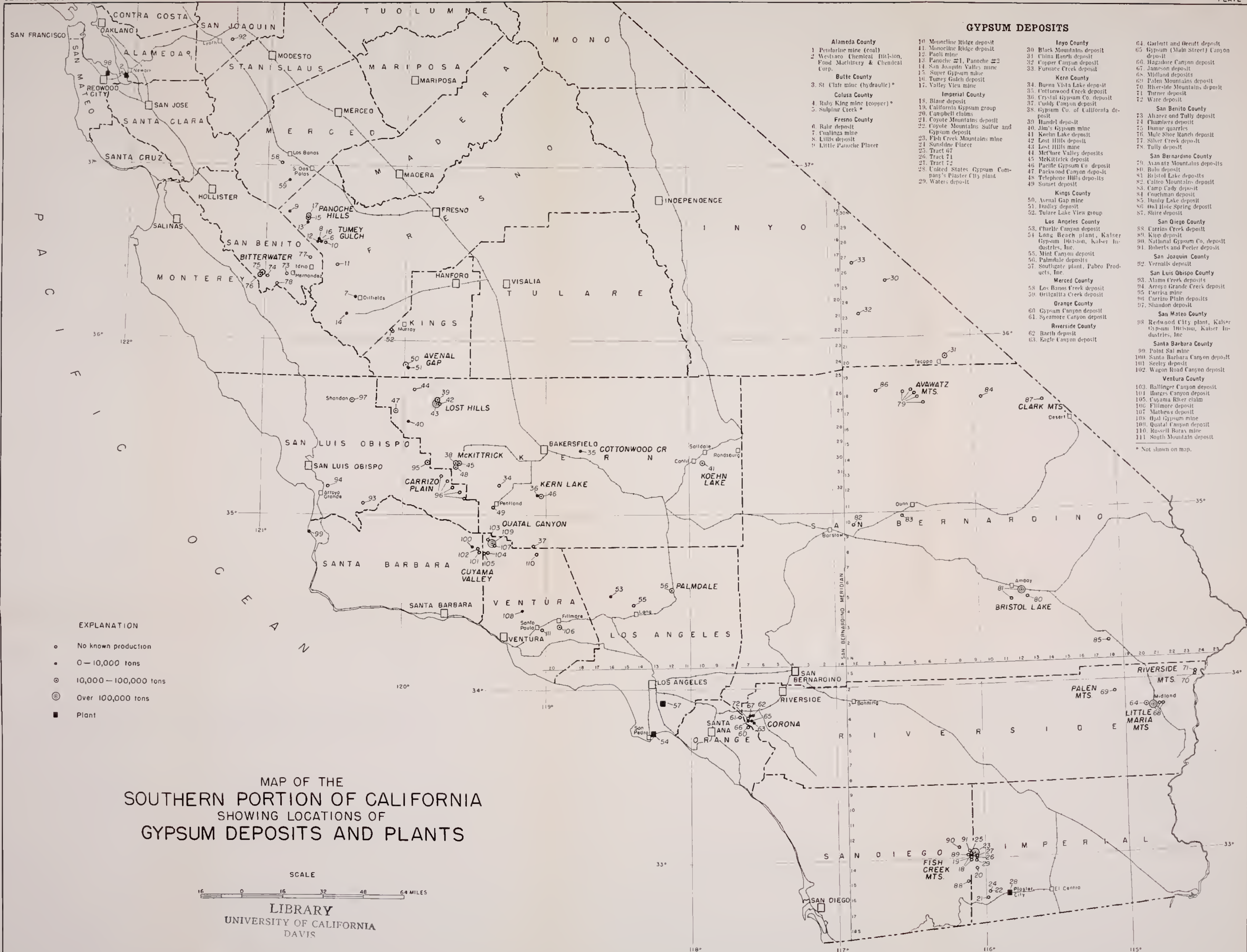

GEOLOGIC MAP OF THE
FISH CREEK MOUNTAINS
IN THE VICINITY OF THE
U.S. GYPSUM COMPANY QUARRY
IMPERIAL AND SAN DIEGO COUNTIES,
CALIFORNIA
GEOLOGY BY W.E. VER PLANCK, APRIL 1950
AND BY T W DIBBLEE JR. 1944
EXPLANATION
Recent
Qal
Alluvium
Tim
Imperial formation
Miocene
g
Gypsum
c
Celestite
Tg
Gray member
Tr
Red member
Split Mt fm
pre-Cret
bc
Granitic and metamorphic rocks
ls
Marble
Fault
Contact
Attitude of beds
Attitude of foliation
LIBRARY
UNIVERSITY OF CALIFORNIA
DAVIS
SAN DIEGO COUNTY
IMPERIAL COUNTY
116°05'
33°00'
FISH CREEK WASH
U S GYPSUM CO. R R
quarry
FISH CREEK MOUNTAINS
N
16°45'
MAGNETIC NORTH
TOPOGRAPHY FROM BARREL SPRING
AND
CARRIZO MOUNTAIN QUADRANGLES
SCALE
0
1/2
1
2 MILES


A
LINE OF SECTION E-W
LINE OF SECTION N63°E
LINE OF SECTION N60°E
A
SW
NE
SCALE
LEGEND
Miocene
Gypsum
Gray member
Split Mountain formation
Pre-Cretaceous
Basement


GYPSUM DEPOSITS
Alameda County
1. Pendarine mine (coal)
2. Westvaco Chemical Division, Food Machinery & Chemical Corp.
Butte County
3. St. Clair mine (hydraulic) *
Colusa County
4. Ruby King mine (copper) *
5. Sulphur Creek *
Fresno County
6. Bair deposit
7. Coalinga mine
8. Lillis deposit
9. Little Panoche Placer
10. Monocline Ridge deposit
11. Monocline Ridge deposit
12. Paoli mine
13. Panoche #1, Panoche #2
14. San Joaquin Valley mine
15. Super Gypsum mine
16. Tumey Gulch deposit
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22. Coyote Mountains Sulfur and Gypsum deposit
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26. Tract 71
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31. China Ranch deposit
32. Copper Canyon deposit
33. Furnace Creek deposit
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34. Buena Vista Lake deposit
35. Cottonwood Creek deposit
36. Crystal Gypsum Co. deposit
37. Cuddy Canyon deposit
38. Gypsum Co. of California deposit
39. Handel deposit
40. Jim's Gypsum mine
41. Koehn Lake deposit
42. Lost Hills deposit
43. Lost Hills mine
44. McClure Valley deposits
45. McKittrick deposit
46. Pacific Gypsum Co. deposit
47. Packwood Canyon deposit
48. Telephone Hills deposits
49. Sunset deposit
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50. Avenal Gap mine
51. Dudley deposit
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72. Ware deposit
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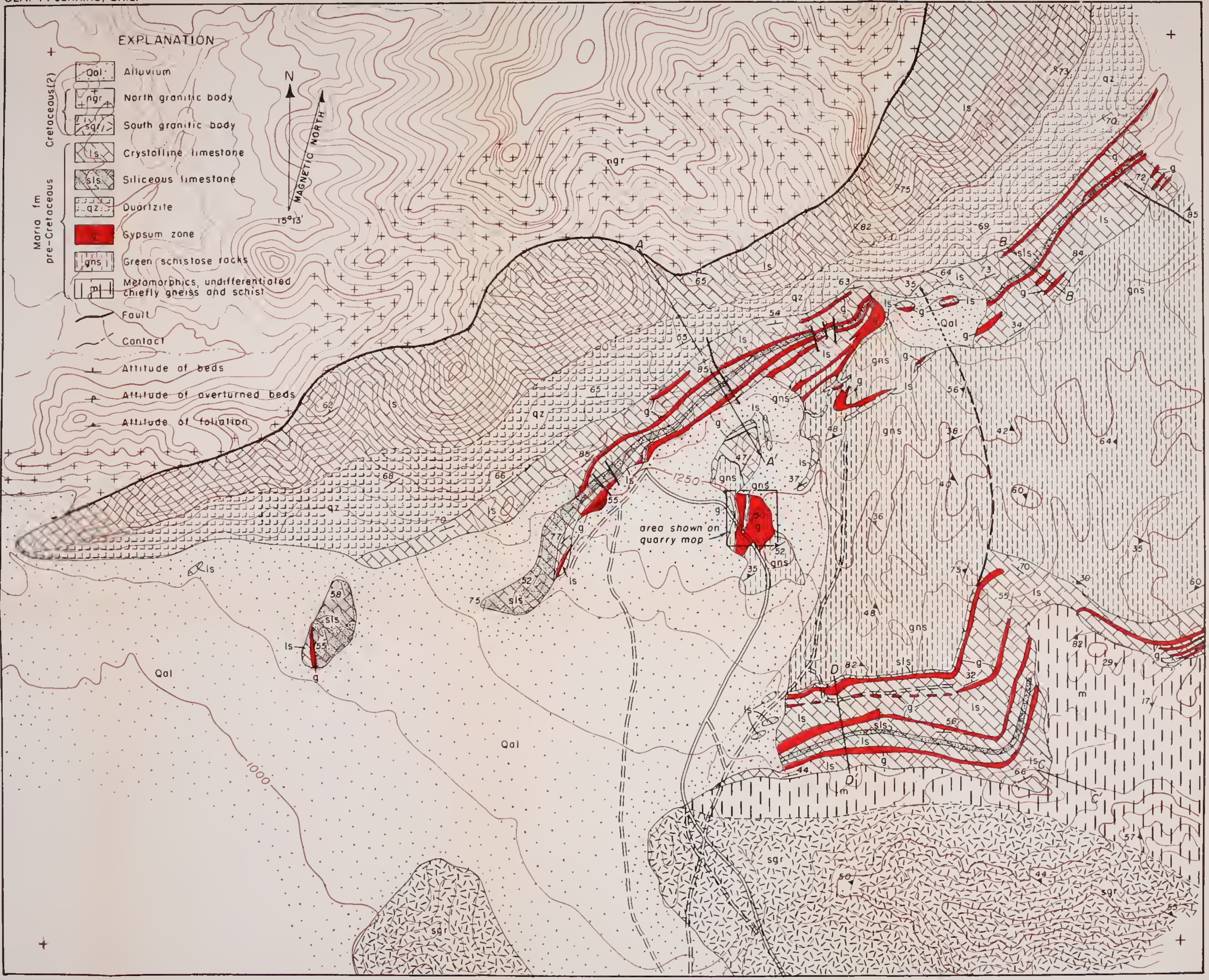
73. Alvarez and Tully deposit
74. Chambers deposit
75. Dunne quarries
76. Mule Shoe Ranch deposit
77. Silver Creek deposit
78. Tully deposit
San Bernardino County
79. Avawatz Mountains deposits
80. Bolo deposit
81. Bristol Lake deposits
82. Calico Mountains deposit
83. Camp Cady deposit
84. Couchman deposit
85. Danby Lake deposit
86. Owl Hole Spring deposit
87. Shire deposit
San Diego County
88. Carrizo Creek deposit
89. Kipp deposit
90. National Gypsum Co. deposit
91. Roberts and Peeler deposit
San Joaquin County
92. Vernalis deposit
San Luis Obispo County
93. Alamo Creek deposits
94. Arroyo Grande Creek deposit
95. Carrisa mine
96. Carrizo Plain deposits
97. Shandon deposit
San Mateo County
98. Redwood City plant, Kaiser Gypsum Division, Kaiser Industries, Inc.
Santa Barbara County
99. Point Sal mine
100. Santa Barbara Canyon deposit
101. Seeley deposit
102. Wagon Road Canyon deposit
Ventura County
103. Ballinger Canyon deposit
104. Burges Canyon deposit
105. Cuyama River claim
106. Fillmore deposit
107. Mathews deposit
108. Ojai Gypsum mine
109. Quatal Canyon deposit
110. Russell Borax mine
111. South Mountain deposit
* Not shown on map.
EXPLANATION
No known production
0—10,000 tons
10,000—100,000 tons
Over 100,000 tons
Plant
MAP OF THE
SOUTHERN PORTION OF CALIFORNIA
SHOWING LOCATIONS OF
GYPSUM DEPOSITS AND PLANTS
SCALE
16 0 16 32 48 64 MILES
PACIFIC OCEAN



GEOLOGIC MAP SHOWING GYPSUM DEPOSITS IN THE LITTLE MARIA MOUNTAINS RIVERSIDE COUNTY, CALIFORNIA

ENLARGED FROM MIDLAND QUADRANGLE

SCALE
1000 500 0 1000 2000 FEET

GEOLOGY BY W E VER PLANCK
MARCH, 1949